Innovation Management and Computing

Artificial Intelligence and Computing Logic

Cognitive Technology for AI Business Analytics

Cyrus F. Nourani
Editor

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Cyrus F. Nourani, PhD, has a national and international reputation in computer science, artificial intelligence, mathematics, virtual haptic computation, enterprise modeling, decision theory, data sciences, predictive analytics, economic games, information technology (IT), and management science. In recent years, he has been engaged as a Research Professor at Simon Frasier University in Burnaby, British Columbia, Canada, and at the Technical University of Berlin, Germany, and has been working on research projects in Germany, Sweden, and France. He has many years of experience in the design and implementation of computing systems. Dr. Nourani's academic experience includes faculty positions at the University of Michigan-Ann Arbor, the University of Pennsylvania, the University of Southern California, UCLA, MIT, and the University of California, Santa Barbara. He was a Visiting Professor at Edith Cowan University, Perth, Australia, and a Lecturer of Management Science and IT at the University of Auckland, New Zealand.

He has taught AI to the Los Angeles aerospace industry and has worked in many R&D and commercial ventures. He has written and co-authored several books. He has over 400 publications in computing science, mathematics, and management science, and he has written several books and has edited several volumes on additional topics, such as pure mathematics; AI, EC, and IT management science; decision trees; and predictive economics game modeling. In 1987, he founded Ventures for computing R&D and was a consultant for clients such as System Development Corporation (SDC), the US Air Force Space Division, and GE Aerospace. Dr. Nourani has designed and developed AI robot planning and reasoning systems at Northrop Research and Technology Center, Palos Verdes, California. He also has comparable AI, software, and computing foundations and R&D experience at GTE Research Labs.

Dr. Nourani commenced his university degrees at MIT, where he became interested in algebraic semantics. He pursued with a world-renowned category theorist at the University of California and Oxford University. Dr. Nourani's dissertation on computing models and categories proved to have pure mathematics foundations developments that were published from his postdoctoral times in US and European publications.

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ABBREVIATIONS

AI	artificial intelligence
AI/ML	artificial intelligence and machine learning
AII	abstract intelligent implementation
ART	adaptive resonance theory
BI&A	business intelligence and analytics
BM	business model
BMMLs	business model modeling languages
BNR	business network redesign
BPML	business process modeling language
BPR	business process reengineering
CC	cognitive computing
CE	circular economy
CEBMs	circular economy business models
COO	chief operating officer
CPUs	central processing units
CWA	closed-world assumption
DARPA	Defense Advanced Research Projects Agency
DL	deep learning
EDI	electronic data interchange
EM	experience management
EPU II	emotion processing unit
FOL	first-order logic
GE	general electric
GF-diagram	generalized free diagram
GPUs	graphical processing units
HTM	hierarchical temporal memory
IA	intelligent agents
IIoT	industrial internet of things
IoT	internet-of-things
IT	information technology
KM	knowledge management
KNN	k-nearest neighbors’ algorithm
KR	knowledge representation
LL	Lady Ligeia

LR	Lady Rowena
ML	machine learning
MoU	memorandum of understanding
NPD	new product development
PCA	principal component analysis
PSIDITP	program synthesis in incomplete domains via inductive theorem proving
PW	perfect women
QDCA	quantum dot cellular automata
RDF	resource description framework
REA	resource-event action
RL	reinforcement learning
SaaS	software-as-a-service
SRPS	symbiotic recursive pulsative systems
XAI	explainable AI

PREFACE

This book explores artificial intelligence (AI) with an importance of managing cognitive processes forward on ontologies for the new frontiers. The volume focuses on new significant accomplishments in areas ranging from neuro-cognition perception and decision-making in the human brain, combining neurocognitive techniques and affective computing, to basic facial recognition computing models, including:

- Agent neurocomputing techniques for facial expression recognition;
- Computing haptic motion and ontology epistemic;
- Morph schemas characterizations for visual analytics;
- Learning and perceptive computing;
- Functional and structural neuroimaging modeling;
- Examining the observed links between facial recognition and affective, emotional processes;
- Interaction of cognitive and emotional processes during social decision-making;
- Neurocognitive processing of emotional facial expressions in individuals;
- Neurocognitive affective system for emotive robot androids;
- Virtual reality-based affect adaptive neuromorphic computing.

It is apparent that industrywide, getting the right information in the right hands at the right time is the key to winning in the digital era to reach goals on the shortest paths. That is one reason why organizations are employing cognitive-based processes. The cognitive advantage is an early insight on driving business value and supports the view that cognitive computing accelerates competitive differentiation. Sixty-five percent of executive surveys indicate that cognitive adoption is very important to their strategy and success, while more than half regard cognitive computing as a must-have to remain competitive. CRM process centers have turned to cognitive technology to provide more efficient and personalized customer service. Personalizing health and wellness cognitive devices allows individuals to gain a better command of their care, help providers scale time and expertise, and let practitioners tailor treatments to specific lifestyle regimens. By boosting productivity and efficiency by using AI cognitive tools to improve their search capabilities, customer care, and workflow management, business leaders are accelerating productivity and efficiency. IBM Watson analytics business coach is a prominent example.

Several chapters of the volume address the above goals, encompassing the newer frontiers from newer foundations to visual AI digital analytics onto value creation, and business model (BM) innovations to digitization applications use cases. The following paragraphs summarize what is accomplished and presented. The scientific AI basis is introduced first, followed by what is applied in the volume for the scientific base, the infrastructure ontologies, business model innovations with predictive analytics, and digitization impacts. The volume starts with examining AI visual computing to forward for affective, haptic, cognitive computing, forward to an AI scientific basis to predictive analytics.

Chapter 2, titled "Cognitive Computing: Quo Vadis?", launches our thoughts on consciousness; that our conscious perception might be the mere surface of our mind, and this, as of the globe, we do not know the interior, but only the crust. The view is that cognitive sciences and neuropsychology convert the qualitative aspects of being a human—our way to reason and learn, our emotions, language, subjective beliefs, and dynamic personality aspects—into something quantitative and sought after in machine learning (ML) and AI. We face the realities that human cognition is not understood well enough to get translated into algorithms and computational hardware architecture. The author aims to describe how cognitive sciences and neuroscience influence AI evolution, what are the current promises and bottlenecks of cognitive computing, and what kind of risks in nascent AI can be mitigated with the help of cognitive science approaches.

The author reviews how some companies are betting on cognitive computing and sketches a prognosis of what to expect in the next few years. Issues are raised on AI implementation and the hype generated by some providers, which might push research and development of AI and cognitive technology into the next "AI winter" and, therewith, increasing risks of cybercrime and privacy erosion. In the second part, the author talks about brain modularity and brain vs. mind concepts, influencing how AI and cognitive technologies are being built. In the third part, she provides a realistic outlook for cognitive computing and talks about the possibility of a quantum future.

Drs. Franova and Kodratoff, from CNRS, France, send us onto a recursive systems views journey onto 'pulsative systems.' Developing and using symbiotic recursive pulsative systems (SRPS) is a source of innovation in various domains that require the handing of evolutive improvement, prevention, and control. The authors explore the history of human thinking and show that what failed in forwarding, perhaps the most important human achievements, was due to a lack of a suitable presentation of fundamental notions behind the construction and the understanding of such systems. The fundamental notion presented for a comprehensive, cohesive achievement retention forwarding option is that SRPS are systemic symbiosis, recursion, and pulsation. In this chapter, we present them intending to underline that the use of standard modular and synergic methods is not appropriate for managing the transmission of knowledge needed for understanding SRPS. To this end, the authors divide module structuring management's approaches into two basic categories. The Newtonian approach is suitable to manage modular systems. Cartesian Intuitionism is suitable to deal with SRPS. They are different, and thus, they are complementary and not competitive with each other. Concrete examples are presented.

The volume starts with the mathematical processes for visual predictive model computing with structural visual structural recursions applying multi-agent AI and Morph Gentzen neuromorphic reasoning. There we observe perhaps realistic visual 'pulsars' on multiagent structures that compute predictive analytics on digitized model diagrams. The volume editor joins the contributing authors with novel model computing techniques with model diagrams for the tableaux with the applications to predictive modeling, forecasting, planning, and predictive analytics support systems. Newer Surface vs. deep digitization analytics are previewed. A novel sequent visual tableaux analytics computation system with a specific mathematical basis is developed. Applications for designing forecasting analytics are examined.

Morph Gentzen's logic from the authors' publications since 1997 is the basis applied to forecast analytics. Surface vs. deep digitization predictive analytics are presented with specific mathematical AI analytics techniques, including nonmonotonic predictive model diagrams. Newer mathematical foundations are developed for the computing science that can forward visual agent computing predictive analytics with applications to interactive predictive analytics. This includes Beth Tableaux's descriptive characterizations the author developed around 2000, for Morph Gentzen sequent, to obtain Morph Gentzen model-theoretic sequent compactness to realize Tableau models. Applications to explaining interactive visual analytics are presented with specific examples from the enterprise modeling industry. Data filtering with keyed functions are novel techniques for a visual surface to deep digitization, while rapid content processing and content delivery are alternate surface digitization functionality realized. Newer examples from industry goals for the innovations areas, for example, interactive analytics or digitization for rapid business automation or enterprise cloud or web interface processing, are examined.

Chapter 4 reaches for the quantum cognitive areas with the chapter by Dr. Nancy Watanbe, Seattle, USA, that presents a quantum theory of cognitive affects with robotic helpers: Newton, arousal, and covalent bonding. The chapter examines the neuroscience of facial recognition psychopathy in the context of artificial intelligence. The investigation begins with her advocacy of robotic helpers as a palliative means to alleviate the cognitive plight and behavioral problems of individuals whose untreated facial recognition psychopathy also represents a risk to the safety and security of their social environment. Contributing to research on facial recognition psychopathy through the textually oriented study of literary representations of reality facilitates the in-depth understanding that may result in helping specialists in the new field of robotics to design devices to enable otherwise handicapped victims of facial recognition psychopathy to participate in their social milieu if they are diagnosed early enough.

The volume moves towards the AI structural and content ontologies and the new important business model values, healthcare, and digitization frontiers. In Chapter 7, titled "AI Process Description Algebras and Ontology Preservation Techniques," the volume editor and colleague Prof. Patrik Eklund, Umeä, Sweden, present a tree computing model with ontology preserving functions that are applied to transform learning across domains with structural morphisms (first author 1992–2005). A computing model based on novel competitive learning with multiplayer game tree planning is applied where computing agents compare competing models to reach goal plans. Goals are satisfied based on competitive game tree learning. The techniques are example prototypes for modeling ontology algebras. For example, the applications to data filtering, robotics processes, class hierarchical transaction morphisms, and exchanges are the newest areas. Modeling frameworks are the natural applications for our event process algebras. Our techniques allow modeling learning across class ontologies and process models based on agent computing structural morphisms to model the ontology transfer processes. Applications to formal concept description are developed with new description logic algebraic models. Novel concept description ontology algebras and concept description ontology preservation morphisms are presented. Based on that new concept, ontology algebras with description ontology algebra preservation theorem are proved.

Moving forward to the enterprise models for businesses, the chapter titled "Digital Transformations Imperatives: Predictive Goal Processes for Business Model Innovation" by the volume editor and his colleague Dr. Annika Sieber, now California, present the business modeling concept characterized by system functions on predictive modeling schemes with prioritized strategic decision systems. Value creation optimizations are considered that are applied to enterprise modeling with new techniques for business mapping to business processes to prove viability. Though we are not alone on the economics ecosystems business modeling process, the systems modeling with structural processes that we invoke are novel concepts that are more concrete techniques for reflecting business models as categorical functions on business process diagrams for EM optimization on economics eco parameters, with morphic reflections on infrastructures, permeated by business model innovations, data-driven decisions on value measures, with direct impact applicability for how a company implements a profitable strategy creating value for both the customer and the enterprise.

The areas explored range from plan goal decision tree satisfiability with competitive business models to predictive analytics models that accomplish goals based on business logic and business processes. Our processes for digitization value creation impacts and AI digitization management strategy areas are previewed. Value creation optimization and dependencies are presented with a startup example. The volume chapter "Digitalization's Effect on Business Model Innovation" by Drs. Gosh and Sieber presents realistic case scenarios for digitization. Though technologies are changing and advancing rapidly, existing companies can, in many cases, not change their businesses fast enough. One factor that affects the pace with which firms change is a clear understanding of how to utilize new technologies for creating and delivering business values. The chapter expands on the body of knowledge about digital transformation and its effect on business models. Based on an empirical study as well as a literature review, digitalization is discussed in regard to its impact on business model innovation. The impacts are illustrated through several business use cases. This paper highlights the impact of advanced technologies on existing and new businesses and how companies are attracting new customers by innovating their business models.

To conclude the volume's thrust, we remind ourselves that by self-learning algorithms that use data mining, pattern recognition, and natural language processing, a computer can mimic the way the human brain works. Introducing cognitive computing and differentiate it from artificial intelligence is an important goal. Examining the difference between artificial intelligence and cognitive computing: In an artificial intelligence system, the system would have told the doctor which course of action to take based on its analysis. In cognitive computing, the system provides information to help the doctor decide. In many cases, a doctor will indeed make the same choice that Watson suggests, but the exceptions are where human experience and judgment become most important. IBM's Watson answers the question, "What's the difference between artificial intelligence and cognitive computing?"

This distinction between artificial intelligence and cognitive computing, and Watson's role in helping humans make decisions, was repeatedly emphasized in presentations throughout the day. Watson analytics was to do the "heavy lifting" for people. For example, healthcare acquired by IBM in 2015 described how radiologists are highly susceptible to "burnout" due to the daunting numbers of images they must examine every day looking for abnormalities as small as several pixels on a five-megapixel monitor. Tolle then described a Watson application under development—code-named Avicenna—that could help them identify the most relevant images among numerous CT and MRI scans.

In addition to specific applications, the process followed might be stated by:

- Evaluate applications for cognitive computing;
- Investigate the impact of Watson on cognitive computing;
- How is cognitive computing applicable in business?
    - Features of cognitive computing;
    - Applications for cognitive computing.

CHAPTER 1

FUNDAMENTAL NOTIONS AND APPLICATIONS OF SYMBIOTIC RECURSIVE PULSATIVE SYSTEMS

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ABSTRACT

Developing and using symbiotic recursive pulsative systems (SRPS) is a source of innovation in various domains requiring to handle evolutive improvement, prevention, and control. However, the history of human thinking shows that the transmission of acquired results failed in most important human achievements due to a lack of a suitable presentation of fundamental notions behind the construction and the understanding of these systems.

The fundamental notions of SRPS are systemic symbiosis, recursion, and pulsation. In this chapter, we present them with the goal to underline that the use of standard modular and synergic methods is not appropriate for managing the transmission of knowledge needed for understanding SRPS. To this purpose, we shall divide management's approaches into two basic categories. The Newtonian approach is suitable to manage modular systems. Cartesian Intuitionism is suitable to deal with SRPS. They are different, and thus they are complementary and not competitive to each other. A concrete example of the SRPS application will be given.

1.1 INTRODUCTION

New technologies of measurements in the physical world and new computational technologies allow Science to go further than it was imaginable a few decades ago. Such an advancement requires a focus on improvement, prevention, and control. This focus is not new in human thinking. However, the notions of improvement, prevention, and control are used even now in somewhat fuzzy versions. Indeed, so far, there has been no systemic paradigm that would provide a coherent and useful systemic presentation of these notions. In the past, these notions were present rather implicitly in philosophical systems. Nowadays, they are present in the same way in management techniques, or they are considered more-less separately in various scientific projects.

In the early eighties, we started to work on a technological vision that will be present in Section 1.7. Since there were no suitable available tools to start with, we have followed Descartes' method. We have had interesting and useful results from the start. Throughout our advancement, we have realized that, due to handling systemic recursion, our interpretation of Descartes' method differs from usual scientific or philosophical interpretations. The three keywords for these differences are symbiosis, recursion, and pulsation. It will be shown that they are directly inherent to a coherent systemic paradigm of improvement, prevention, and control.

Modern Science and philosophy consider synergy and modularity instead of symbiosis, non-recursive complexities instead of recursion and constant change or mutations instead of pulsation. While these modern Science notions are extremely useful and relevant for many real-world applications, they cannot replace symbiosis, recursion, and pulsation without destructive consequences. This means that the approaches of these two groups of notions are complementary and non-competitive.

For convenience, we shall call the *first group* the one containing the notions:

- Symbiosis;
- Recursion;
- Pulsation.

And *second group* that of containing the notions:

- Synergy, modularity;
- Non-recursive complexities;
- Change, mutations.

We shall present below reasons for naming *Cartesian Intuitionism* a systemic paradigm based on the first group and *Newtonian approach* a systemic paradigm based on the second group of notions. We shall call symbiotic recursive pulsative systems (SRPS) the systemic nucleus of Cartesian Intuitionism.

We shall give below a systemic description of the first group notions as well as a presentation of a coherent and useful model for improvement, prevention, and control. It will be shown that the management of Cartesian Intuitionism projects significantly differs from Newtonian ones.

The chapter is organized as follows: Section 1.2 specifies the notion of symbiosis as understood in this chapter. Section 1.3 introduces recursion as a way of representing action, control, and prevention. It explains what we mean by systemic recursion. Section 1.4 introduces the notion of oscillation as a representation of a one-level creation process used in pulsation presented in Section 1.5. Section 1.6 presents a motivation for the introduction of systemic difference between the Newtonian approach and the Cartesian Intuitionism. It will become clear why the latter expression is used to describe the systemic Science relevant to SRPS. Section 1.7 presents a technological vision for which handling SRPS is relevant.

1.2 SYMBIOSIS-REPRESENTATION OF 'VITAL INTERDEPENDENCE'

Symbiosis is a particular composition. In this section, we shall define of symbiosis as used in this chapter. We shall also compare symbiosis to another kind of composition, namely synergy and fusion. We shall start with an intuitive description before going into more formal details.

By symbiosis, we understand a composition of two or several parts that is separation-sensitive. This means that a separation of one or several parts leads to extinction or irrecoverable mutilation of the whole and all the involved parts.

In contrast to this, by synergy, we understand a composition of parts that is not separation-sensitive. Sometimes, synergy is also called modular composition.

In the case of fusion, the resulting composition is homogenous. It does not allow to recognize the involved parts, they are blended, such as in a fusion of metals. We shall now give several examples.

1.2.1 PICTORIAL SYMBIOSIS

Let us consider our imitation of the well-known puzzle-like picture of 'two women in one (see, for instance, Weisstein (2021) (Figure 1.1).

A similar picture is known as E.G. Boring's version of one of the 'Devinettes d'Épinal.' Different overlapping features show either a young or an old woman. The important point is that the features necessary to see the young or the old woman are common to both visions, say for example, their ‘little chin versus big nose’ or their ‘necklace versus lips’ features. If we withdraw these common features common to different interpretations, the women disappear, only leaving their common coat and a decorative feather in their hair (Figure 1.2).

FIGURE 1.1 Old-young lady illusion.

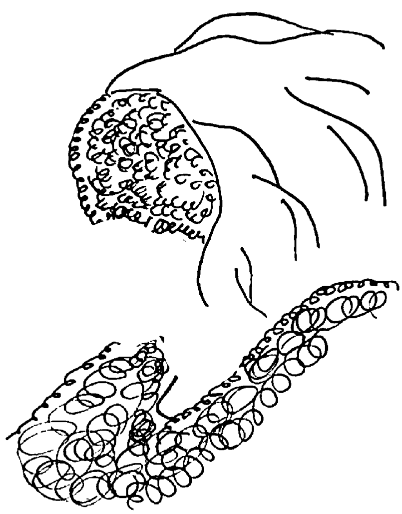

FIGURE 1.2 A mutilated version of old-young lady illusion.

This defines a symbiotic pictorial occurrence of both women, that is, there exists a subset of features (here, almost all of them, but this not necessary) such that deleting them from one occurrence induces an unrecoverable loss in both occurrences.

1.2.2 REPRESENTATIONAL SYMBIOSIS

A careful study of definitions of Euclid's geometry objects shows that these definitions are symbiotic. This means that eliminating even one notion would either render meaningless the resulting system (i.e., extinction of the resulting system) or the meaning of the resulting system would be completely different (i.e., irrecoverable mutilation).

It should be noted here that the example of Euclid's geometry illustrates well the fact that the constituents of a symbiotic system need to be handled as symbiotic in the construction process of such a system. However, after its successful final creation, the use of these notions may, in some cases, be modular. For instance, when we use the notion of point while working in Euclid's geometry, we do not need to be aware of the symbiotic dependence of this notion on other notions of the same geometry. However, such awareness was necessary for Euclid when he created this geometry.

1.2.3 INTENTIONAL SYMBIOSIS

As far as intentional symbiosis is concerned, we consider it exclusively in relation to human artificial creations. The detection of intentional in nature processes is out of the scope of this chapter.

We could perceive a slight glimpse of intentional symbiosis in all the above, rather static, examples. Even though present, a rather procedural character of intentional symbiosis was not mentioned. In the next section, we shall give an example of the construction of Ackermann's function, where such an intention will be easily describable and thus comprehensible.

In the following part, we shall give further examples of symbiosis in relation to recursion and pulsation. The above examples and descriptions make meaningful the following definition.

- **Definition 1.2.3.1: Symbiosis:** By symbiosis, we understand a composition of two or several parts which is separation sensitive.

1.3 RECURSION-REPRESENTATION OF ACTION, CONTROL, AND PREVENTION

This section is not intended as an introduction to mathematical recursion. It is intended only as a presentation of a minimal, but sufficient basis for understanding *systemic recursion* for SRPS.

Mathematical and computational recursion handle recursion from formal or programs efficiency points of view (see Gries, 1981; Kleene, 1980). Recursion, in these cases, is a known tool and not a science. In contrast to this, systemic recursion is a *science of know-how for creating recursive systems* that are useful for real-world applications in various domains. We shall point out the main features of systemic recursion throughout this chapter. We shall use the term systemic recursion also for recursion in systems created by this particular Science.

1.3.1 PRELIMINARY DEFINITIONS AND NOTIONS

Roughly speaking, recursion is a particular way to represent, by a finite set of rules, potentially infinite systems and processes (actions and creations). These rules are expressed in terms of basic action or creation operators called constructors.

In Mathematics and Computer Science, such constructors are usually known, available or easily attainable in standard know-how. In contrast to this, the know-how of systemic recursion lies in a progressive invention of on-purpose constructors of a goal system depending on a progressive invention of a *formal specification* of the goal system. Indeed, in systemic recursion, we start to build a system from an *informal specification* of the goal system.

By informal specification of a real-world application, we mean that it is not yet a formalized description. It is, for instance, the case for technological visions. An informal specification is usually not formulated by a mathematician or by a computer scientist. It is formulated by a visionary person or by experts expressing a need for some new solving tools in their domain. Informal specification describes a vague 'what' of the intended application, tool or system.

When an informal specification of a technological vision is known, the 'how' of its implementation is usually not available and may even be unknown or impossible in standard know-how. Therefore, in systemic recursion, we speak of research or creation rather than of development. Since not all the constructors of the intended system are known at the beginning, a long period of preliminary research of a sufficient set of relevant constructors always precedes the implementation of a final product or an experimental prototype. Even the final development can require some complementary inventions.

The goal of systemic recursion is to pass from an informal specification to a satisfactory formal specification of the goal together with the relevant on-purpose knowledge and know-how, i.e., ‘how’ or ‘procedural science’ of the actual development. A formal specification is a *satisfactory definition* of ‘what.’

This means that, in systemic recursion, a formal specification is an agreed-upon compromise between the visionary and the developers for the considered informal specification. This compromise is built up progressively. It cannot be created in advance. This is because, in systemic recursion, research is ‘pluridisciplinary’ in the sense that it crosses the traditional boundaries between disciplines and it progressively constructs its on-purpose knowledge, know-how, and boundaries. It thus differs from multidisciplinary research, which is simply a clever combination of the knowledge of existing fields.

In the following part, we are going to consider recursion when it concerns systems at first, and then actions in such systems. We shall go from an informal specification of a system to its formal specification. This will be an opportunity to mention the notion of incompleteness of a system. In Section 1.5, we shall then present a model for a progressive completion of incomplete systems.

1.3.2 EXAMPLE: FROM AN INFORMAL TO A FORMAL SPECIFICATION

We are going to illustrate such a progressive construction of a recursive system described by an informal specification. On a sufficiently big table consider a stack of blocs a, b, c, d, and e as shown in Figure 1.3.

If a block n is on the top of a block m, we say that n is top of m written as: n = top(m). There is at most one block on the top of another one. Our goal is to formalize a set of all blocks, that is, an infinite prolongation of this stack.

We shall denote SB the resulting system of blocks. Let us start now formulating the rules that will formally express SB.

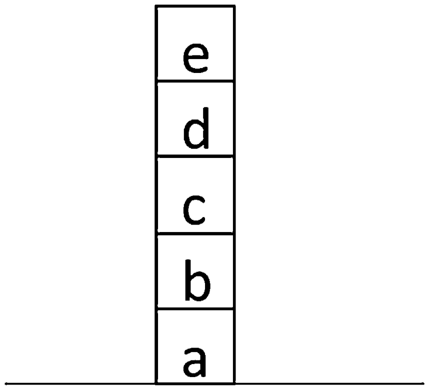

FIGURE 1.3 A stack of blocks.

First of all, there is a block that is directly on the table. We shall call it a_{Table}. This is the basic constructor (similar to 0 in natural numbers). We shall use the symbol ∈ to denote the relation 'belongs to.' We thus have the first rule:

- **($R1_{SB}$):** $a_{Table} \in SB$

The second rule is as follows:

- **($R2_{SB}$):** if m ∈ SB then top(m) ∈ SB

The descriptor 'top' is here a general constructor (similar to the successor function in natural numbers). Note that if top(m) were identical to a_{Table} for some m, ($R2_{SB}$) would bring no new element to SB. We shall, therefore, introduce the next generalized rule that guarantees that such a situation does not happen:

- **($R3_{SB}$):** if m ∈ SB then top(m) $\neq a_{Table}$.

We thus have at least two different elements of SB.

Now, we want to express that two different elements of SB have as tops two different blocks. This gives us the following rule:

- **($R4_{SB}$):** if m ∈ SB, n ∈ SB and top(m) = top(n) then m = n.

Finally, we want to express the fact that the above construction rules define exactly the set SB. To express this, it is sufficient to add the following rule:

- **($R5_{SB}$):** if M is a set such that:
  - o -$a_{Table} \in SB$

- o for every $w \in SB$, if $w \in M$ then $top(w) \in M$
- o then M contains every element of SB.

SB is defined recursively by the above rules. In other words, SB is defined in terms of itself. We say that SB is a recursive system.

We shall now define what we mean by a potentially infinite set. By a potentially infinite set we shall understand any pragmatically useful, possibly finite set, that may be rendered infinite by a formalization (thus by an abstraction).

This definition is a useful reminder tool while handling real-world systems that have a finite but not a fixed number of elements.

1.3.3 INCOMPLETE FORMAL SPECIFICATIONS

The above example of formalization of a set of blocks in a stack is interesting since it enables us to point out a largely occurring phenomenon in the formalization process of real-world applications, namely incompleteness.

In formal systems, incompleteness of a formal system means that there is a statement A such that A and not(A) are true in different interpretations of the considered formal system, but neither A nor not(A) are provable in the framework of the system.

When the research starts from an informal specification of a system, not all the relevant rules may be perceived from the start. For instance, while we might think that we have successfully formalized our intended situation represented by a stack of blocks, we might not be aware that, syntactically, the above formal rules are indistinguishable from a formal system corresponding to another situation.

For instance, let us consider a particular system that will be called perfect women (PW). This system will be composed of historically known Socrates' wife Xanthippe and all of her direct feminine ancestors. By direct feminine ancestors, we understand her mother, mother of her mother and so on. We assume that there is exactly one mother to each element of this system. In other words, 'mother_of' is a function in a mathematical sense.

The following formal rules seem to correspond to our intention to define PW:

- **($R1_{PW}$):** Xanthippe $\in$ PW.
- **($R2_{PW}$):** if $m \in PW$ then mother_of(m) $\in$ PW.
- **($R3_{PW}$):** if $m \in PW$ then mother_of(m) $\neq$ Xanthippe.

- **($R4_{PW}$):** if m ∈ PW, n ∈ PW and mother_of(m) = mother_of(n) then m = n.
- **($R5_{PW}$):** if M is a set such that:
  - o Xanthippe ∈ PW
  - o for every w∈ PW, if w ∈ M then mother_of(w) ∈ M
  - o then M contains every element of PW.

This new system can be obtained from the one for 'blocks' by a second-order substitution {a_{Table} → Xanthippe, SB → PW, top → mother_of }. The two systems have the same structure, but they deal with different objects.

We can see that, syntactically, the two above formal systems are identical, while they are intended to describe different situations. We can now consider another system, namely the system known as Peano's axioms for natural numbers:

- **($R1_N$):** 0 ∈ N.
- **($R2_N$):** if m ∈ N then Suc(m) ∈ N.
- **($R3_N$):** if m ∈ N then Suc(m) ≠ 0.
- **($R4_N$):** if m ∈ N, n ∈ N and Suc(m) = Suc(n) then m = n.
- **($R5_N$):** if M is a set such that:
  - o -0 ∈ N
  - o -for every w∈ N, if w ∈ M then Suc(w) ∈ M
  - o then M contains every element of N.

We observe here that these three formal systems are syntactically identical. To give a name to this situation where several systems are identical modulo a second-order substitution, we shall say they have the same recursive nucleus. Since they correspond to different intentions (models), these systems are incomplete.

In other words, a recursive nucleus is a set of rules that recursively defines several different systems that have to be therefore distinguished by adding complementary rules that correspond to relevant pieces of information handled by the intended system. For instance, we can obtain the system NAT known as Peano's arithmetic, obtained from N by adding the rules recursively defining the addition and multiplication:

- **($R1_{NAT}$):** 0 ∈ NAT.
- **($R2_{NAT}$):** if m ∈ NAT then Suc(m) ∈ NAT.
- **($R3_{NAT}$):** if m ∈ NAT then Suc(m) ≠ 0.
- **($R4_{NAT}$):** if m ∈ NAT, n ∈ NAT and Suc(m) = Suc(n) then m = n.

- **($R5_{NAT}$):** if M is a set such that:
    - o -0 $\in$ NAT
    - o -for every w$\in$ NAT, if w $\in$ M then Suc(w) $\in$ M.
    - o then M contains every element of NAT.
- **($R6_{NAT}$):** 0 + n = n.
- **($R7_{NAT}$):** Suc(m) + n = Suc(m+n).
- **($R6_{NAT}$):** 0 × n = 0.
- **($R6_{NAT}$):** Suc(m) × n = m × n + n.

We shall not consider the corresponding relevant extensions for SB and PW. These systems are here only to point out that, in working with real-world applications, we often work with incomplete systems. This hints at the importance of building a first recursive nucleus for a particular application in a way that enables to extend it harmoniously. By a harmonious extension, we shall understand a situation in which no rule considered as important in one stage is rejected or considered as a too strong requirement in future stages. This also means that, at each particular level of evolution, a system of rules is sufficient to solve the considered problems; we say that it is practically complete. It needs to be open and flexible for a possible need of supplementary rules that will allow to solve some new problems of interest. We shall speak of open evolution by a need or a desire to solve further problems. This means that, when incomplete systems are concerned, we do not focus (as mathematicians do) on *decisions* such as whether a problem is solvable in a considered theory of a system. Instead, for a given problem, we try to *construct a solution* that may require the given theory to be completed by particular rules enabling to solve the problem in the extended version.

Scientific revolutions are a typical example of knowledge acquisition that is not harmonious in our sense. Indeed, some scientific revolutions reject some rules of the previously formalized systems. We shall describe later a method called 'pulsation' that is one kind of such a harmonious modification. The notions of harmonious extension and practical completeness are described here only informally. Further work must be done to provide more formal definitions.

So far, we have considered recursive systems, namely from the point of view of their recursive formalization. In the following section, we shall show how recursive actions may be considered as a way to represent not only actions but also a particular kind of control.

1.3.4 RECURSION AS A WAY TO REPRESENT A PARTICULAR CONTROL

In this section, we shall present an example that illustrates how recursion captures in itself symbiotic dependency of all the secondary effects and the effect of a computation of a simple recursive procedure. Let us point out that we emphasize here symbiotic information, not symbiotic computation.

Let us consider the following simple problem. On a sufficiently big table consider a stack of blocs a, b, c, d, and e as shown in Figure 1.4.

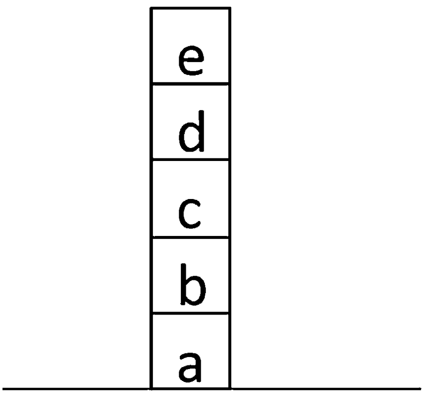

FIGURE 1.4 A stack of blocks.

We say that a bloc m is clear if there is no other bloc on m (in Figure 1.4. bloc e is clear.). There can be at most one bloc on the top of the other. If n is on the top of m, we say that n is top of m written as: n = top(m). Let us consider the following procedure make clear:

```
makeclear(x) =
        if      x is clear then procedure is completed
        else
                if          top(x) is clear
                then        put(top(x)) on table
                else        first       makeclear(top(x)) and
                            then              put(top(x)) on table
```

It can easily be checked that makeclear(b) results not only in clearing the bloc b but also in the situation where blocs c, d, and e are clear and on the table. This means that the procedure makeclear contains in its description not only its direct effects (such as: the bloc b is cleared) but also the full description of all the secondary effects of any action performed. In Figure 1.5. these secondary effects are that the blocks c, d, and e are on the table.

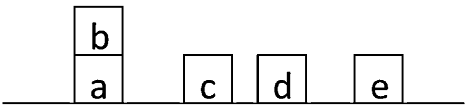

FIGURE 1.5 A modification of the environment after clearing b.

For some primitive recursive procedures, the secondary effects do not modify the environment, but this should not be a barrier for the general perception of primitive recursive procedures to be seen as invisible procedural ‘seeds’ containing symbiotically related effects (i.e., the results of the computations) and the secondary effects (i.e., the consequences of the computation of a particular value). Therefore, implementing recursive procedures is interesting in all environments where control over the secondary effects is important.

It may not be straightforward to see in what sense we speak of symbiotically related the effects and the secondary effects. Let us recall that symbiosis of information means here that if we take away one information, then all information becomes distorted, or mutilated.

Let us consider therefore the instruction makeclear(b). This means that, step-wise, all blocks above b have to be put on the table leading to the result that the blocks c, d, and e are on the table. Let us suppose that we take away the information that the block d is on the table. However, in the progression of the procedure, if we call makeclear(b) first, we have to call makeclear(c), then makeclear(d). Since top(d) is e and it is clear, we may put e on the table. d = top(c) is now clear, but we cannot put it on the table since this information has, by our assumption, been missing. This means that the whole process is stuck and we then cannot put block c on the table. So, the resulting information is mutilated since it does not express all the potential of the procedure makeclear. Moreover, there is no evidence that the information that the block e is on the table is related to the procedure makeclear. It could, in principle, be related to other procedures.

The above procedure makeclear is an example of primitive recursion. A recursion that is not primitive goes even further in representing symbiotically information that concerns control, rigor, and reproducibility. Ackermann’s function is the simplest example of a non-primitive recursive function. Therefore, it is a suitable representative for explaining how non-primitive recursion modelizes a particular kind of pulsation in SRPS.

In the following part, we shall give a formalized presentation of the pulsation, starting with a presentation of a construction procedure that result in Ackermann's function. It will become clear how this construction and the notion of pulsation are linked together.

1.3.5 A CONSTRUCTION OF ACKERMANN'S FUNCTION AND A 'SIMPLIFICATION' OF ITS COMPUTATION

The idea to model pulsation by Ackermann's function comes from the understanding of how this function may be constructed. The practical use of this function becomes then exploitable by a 'simplification' the computation of its values using the knowledge of its construction process.

1.3.5.1 A CONSTRUCTION OF ACKERMANN'S FUNCTION

Let ack be Ackermann's function defined by its standard definition, i.e.:

$$ack(0,n) = n+1$$
$$ack(m + 1,0) = ack(m,1)$$
$$ack(m+1, n+1) = ack(m,ack(m+1,n)).$$

We shall show here how this function can be constructed.

Since ack is a non-primitive recursive function, by definition of non-primitive recursion, it is a particular composition of an infinite sequence of primitive recursive functions. We shall thus define a function ack' as a particular composition of an infinite sequence of primitive recursive functions and it will be clear then that the definitions of ack and 'ack' are identical.

By definition of a primitive recursive function, each primitive recursive function f is a composition of a finite number of primitive recursive functions and of 'f' itself. Let us, therefore, construct such an infinite sequence of primitive recursive functions f_0, f_1, f_2, …, f_n, f_{n+1}, …. We define:

$$f_0(n) = n+1$$
$$f_{i+1}(n+1) = f_i(f_{i+1}(n))$$

for each i from 0, 1, 2…. We are thus able to define a new function ack' as follows: $ack'(0,n) = f_0(n)$ and $ack'(m + 1, n + 1) = f_{m+1}(n+1)$. Note that $ack'(m + 1,0)$ is not yet defined. Since we want ack' to be a non-primitive recursive function, we need to guarantee that it cannot be reduced to any of f_i. To do so we shall simply perform a diagonalization on this infinite sequence of functions by defining:

$f_{i+1}(0) = f_i(1)$.

In other words, we define:

$ack'(m + 1,0) = f_m(1)$.

By this construction, we see that f_{i+1} is more complex than f_i for each i. It is obvious that:

$ack'(m,n) = ack(m, n) = f_m(n)$.

This construction is at the same time a guarantee that ack is not primitive recursive, since it is indeed a composition of an infinite sequence of primitive recursive functions, each of them more complex than those before it and ack cannot be reduced to any one of them. As a by-product, we have thus simplified also the standard presentation of the non-primitive character of ack which is usually done by a proof by a projection of Ackermann's function back into a sequence of primitive recursive functions $a_m(n) = ack(m,n)$ and showing that ack grows more rapidly than any of these primitive recursive function (see Yasuhara, 1971). The difference thus lies in our use of an indirect construction (instead of a projection) and relying on a diagonalization.

1.3.5.2 A PARTICULAR SIMPLIFICATION OF THE COMPUTATION OF ACKERMANN'S FUNCTION

The above construction of Ackermann's function shows immediately that the computation of its values for given m and n using non-primitive recursive definition can be simplified by a definition of m primitive recursive functions obtained by a suitable macro-procedure.

Our recursive macro-procedure will simply compute, step by step, each of the values $f_{i+1}(0)$ in advance and will define the whole f_{i+1} with this already computed value. This may not lead to a fast computation, but we are not concerned now with the computational efficiency of this way of proceeding, only by its practical feasibility and reproducibility.

We define a macro-procedure, ack_macro. Our ack_macro uses the standard LISP procedures add_to_file and load_file. The procedure add_to_file(*text*,*F*) adds the *text* at the end of the file *F*. The procedure load_file(*F*) loads the file *F* to make computable the functions written in the file. We create at the start an auxiliary file F that stores the functions f_i generated by ack_macro. Our macro-procedure ack_macro(m,n) uses the infinite sequence of functions defined above as being representative of Ackermann's function (Figure 1.6).

```
Step 1:
      text:= { f0(n) = n+1 }
Step 2:
      Create the file F (empty at start) and
      add_to_file(text,F)
      load_file(F)
Step 3:
      i:=0
      aux:= compute the value of fi(1)
Step 4:
      text := {   fi+1(0)= aux and fi+1(n+1)= fi(fi+1(n))}
      add_to_file(text,F)
      load_file(F)
      aux := compute the value of fi+1(1)
      i:= i+1
      if i < m
      then Go to step 4
      else stop
```

FIGURE 1.6 A macro-procedure for computing particular values of ack.

ack_macro(m,n) is now completed and file F collects the definitions of m primitive recursive functions. We are now able to compute ack(m,n) = f_m(n), where the definition of f_i from the file F is used for all i = 0, 1, …, m.

On the internet, we can find several programs that compute Ackermann's function values faster and much further than our presented macro-procedure. The problem with those programs is that they are based on the knowledge that Ackermann's function can be represented as a generalized exponentiation function. The advantage of our presentation lies in its suitability for practical purposes in the following sense. As we shall see with the notion of pulsation, complex real-world problems may require modelization by non-primitive Ackermann's like programs that will not be reducible to an arithmetic generalized exponentiation. In other words, it is useful to consider non-primitive recursion that is defined not for natural numbers, as it is the case for Ackermann's function, but that is defined for practically useful and exploitable recursive systems.

1.3.5.3 PREVENTION AND CONTROL ARE MODELIZED BY ACKERMANN'S FUNCTION

We have seen above in the example of the program makeclear that primitive recursion captures the effects (the value of the computation) and the secondary effects (the consequences of the computation that are the intermediary values that are the results of the same procedure). We have also seen that the non-primitive recursive Ackermann's function is obtained using the diagonalization procedure. This diagonalization brings forward complementary information about the process of this symbiotic information in the recursion. Since diagonalization is a meta-level procedure, we understand this complementary information as a kind of meta-level prevention from primitive recursion reducibility. In other words, we interpret it as a prevention factor simply because diagonalization prevents ack to be reduced to computation and consequences of computations of functions from which it is constructed.

It is interesting to note that some scientists may intuitively 'feel' that Ackermann's function provides a model of human thinking of 'everything' for a particular situation. The above-mentioned 'makeclear' program shows that this intuition can be presented in terms of symbiosis of the information included in a particular situation. Note that the above macro-procedure (Figure 1.6) simplifies only the computation of thinking of 'everything.' To illustrate this simplification of the computation we may mention that, as it can be checked, the trace of the computation of the value for ack(3,2) using standard definition shows (see Franova, 2008); that the value ack(1,1) is computed 22 times for obtaining the result of ack(3,2). This is not the case for the computation of simplified $f_3(2)$. However, it is necessary to understand that the overall complexity of this situation remains the same since, to be able to 'simplify' (i.e., to define the above macro-procedure), we already need to have available Ackermann's function equivalent sequence of f_i. In other words, the principle and effectiveness of 'thinking of everything' remain on the global level. The simplification concerns only focusing on one particular local level defined by the two values a and b, instantiating Ackerman's variables. Of course, the macro-procedure is general, but for a and b given, it generates only the finite sequence of primitive functions f_0, f_1, …, f_a.

This makes explicit that 'thinking of everything' keeps its order of complexity after applying our simplification.

Systems requiring a simultaneous handling of the prevention and control factors such as information security systems or strategic planning in flexible environments are practical examples of a problem requesting to think of 'everything.'

1.3.6 SYSTEMIC RECURSION

In the previous sections, we have presented what can be seen as a recursive structure. In a recursive structure, there is an obvious so-called base step element (for instance, Xanthippe, a_{Table}, and 0 in our previous examples). We shall speak about systemic recursion when a system is defined or constructed recursively, but there is no such an obvious 'element.' It is mostly the case when all the parts of the system may themselves be considered as symbiotic systems. In other words, in systemic recursion, symbiotic constructors are also systems.

To give a simple example, we may consider a method M that is defined recursively and in terms of a finite number of complex symbiotically dependent rules (procedures) R_1, R_2, …, R_n. Then, a systemic equation for such a method can be represented in the following way:

$$M = R_1 + R_2 + \ldots + R_n + M.$$

Since the whole, i.e., the method is symbiotically interrelated with the rules R_1, R_2, …, R_n, the order of these rules in the equation is a question of convenience rather than necessity. Of course, the rules R_1, R_2, …, R_n may be recursive procedures themselves. Thus, we can see that the notion of systemic recursion is rather complex.

We believe that it is obvious that systemic recursion is different from linear-like, tree-like or network-like representations.

The above construction of Ackermann's function and our particular simplification of its computation by a primitive recursive macro-procedure allows us to consider it as a model for a particular kind of pulsation. The notion of oscillation provides an informal background for the notion of pulsation presented later in Section 1.5.

1.4 OSCILLATION-REPRESENTATION OF A ONE-LEVEL CREATION PROCESS

In scientific fields the obvious basic paradigm is, for a given problem, to find an idea leading to a solution. This can, in general, be expressed by the formula:

$$\forall \text{ Problem } \exists \text{ Idea Leads\_to\_a\_solution(Idea,Problem).}$$

We shall call this formulation: “first paradigm.”

However, another, and rather unusual (except in Physics) paradigm is to find an idea that provides a solution for all problems. We shall show how Ackermann’s function provides a model for this second paradigm. Similarly, to Ackermann’s function, in a sense, it is a kind of ‘thinking of everything.’ First, however, let us express this paradigm by the formula:

$$\exists \text{ Idea } \forall \text{ Problem Leads\_to\_a\_solution(Idea,Problem).}$$

We shall call this formulation: “second paradigm.”

The difference between these two formulas lies in the fact that, in this second case, the ‘Idea’ obtained is unique, while in the first formula, each problem can use its own idea.

We call oscillation this approach of *symbiotic* switching between the two above paradigms.

The oscillation may be performed in the following way. We start to consider a large variety of problems for which we try to find an idea for a general solution to all of them. This solution needs to be open to the need for further improvement. We shall introduce a particular kind of such an improvement in the next section.

1.5 PULSATION-REPRESENTATION OF ‘EVOLUTIVE IMPROVEMENT’

1.5.1 PULSATIVE SYSTEMS ARE MODELIZED BY ACKERMANN’S FUNCTION

The above sections will help us explaining how Ackermann’s function enables us to formally specify the notion of pulsation. This is interesting not only from the point of view of building particular formal theories for unknown domains but also for understanding the difference between revolution, innovation, and evolutive improvement in this building process.

Let us consider a potentially infinitely incomplete theory. In unknown environments that may be seen as a framework for potentially infinitely incomplete theories, building a formal theory becomes then a process of *suitable completions* of a particular initial theory T_0. We shall say that this theory T_0 is practically complete when it formalizes solutions for the problems that have been met so far. Since the theory is potentially incomplete, sooner or later we shall meet a problem that cannot be solved in the framework of T_0. In the vocabulary of scientific discoveries, we may say that we need a conceptual switch (a new axiom or a set of axioms) that *completes* T_0. Note that we speak here about *completion* and:

- Not about a *revolution*-which would mean in a sense rejecting T_0;
- Not about an *innovation*-which may simply mean a particular reformulation of T_0.

So, this completion T_1 contains T_0 and thus it is coherent with T_0. However, since a new conceptual switch guarantees that T_1 is more powerful than T_0, we consider this particular kind of completion as a suitable model for one step of *improvement* in our search for suitable completions. Since we consider here a potentially infinitely incomplete theory, we can then see the pulsation as an infinite sequence of theories T_0, T_1, …, T_n, …. In this sequence, T_{i+1} completes and is coherent with T_i for all i = 0, 1, 2, …

We have seen that, in the infinite sequence from which Ackermann's function is built, the function f_1 relies on (is coherent with) f_0, and f_{i+1} relies on f_i for each i. We can, therefore, see that Ackermann's function really provides a model for evolutive improvement (or progress in Bacon's sense (Bacon, 1994)) and we understand it different from revolution and innovation.

Let us now come back to our notion of pulsation. We have seen that, in the informally specified notion of oscillation, we switch coherently between two paradigms. In our interpretation, the second paradigm, i.e.:

$$\exists \text{ Idea } \forall \text{ Problem Leads\_to\_a\_solution(Idea,Problem)}$$

represents the idea of Ackermann's function and the first paradigm, i.e.:

$$\forall \text{ Problem } \exists \text{ Idea Leads\_to\_a\_solution(Idea,Problem).}$$

represents particular primitive recursive functions from which Ackermann's function is constructed. In the definition of Ackermann's function, we have seen that:

$$f_{i+1}(0) = f_i(1)$$

Analogously, we shall state that the sequence of completing theories can be written as:

$$T_{i+1} = T_i + A_{i+1}$$

where; A_{i+1} is an axiom or a set of axioms representing the conceptual switch that enables solving the problem unsolvable in T_i and solvable in T_{i+1}.

Let us stress the fact that by pulsation we understand an infinite sequence of theories T_0, T_1, …, T_n, T_{n+1}, … with the just mentioned property and not only one particular step in this sequence. This means that pulsative systems are systems that are formalized progressively and potentially indefinitely.

1.5.2 PREVENTION AND CONTROL FACTORS ALREADY EXIST IN T_0

We have seen above that Ackermann's function is also a model for symbiotic consideration of prevention and control.

Let us return therefore to the construction of Ackermann's function. We could see that, with respect to our requirement to obtain a non-primitive recursive function, f_0 must be defined in a way that guarantees the non-primitive recursion of the final composition of the constructed infinite sequence. Indeed, if f_0 were a constant, for instance, 3 (which would mean that $f_0(n) = 3$ for all n), the resulting infinite composition would also be the constant 3. This means that, even though f_0 is the first function of this infinite construction, since it must be defined as a symbiotic part of the final composition, the prevention and the control factors must be present already in this function.

So, we can see that Ackermann's function provides a model for the pulsation that intends and guarantees symbiotic handling prevention and control already from the start.

1.6 PUTTING IT TOGETHER: SRPS AND CARTESIAN INTUITIONISM

In the previous part, we have introduced the notions of symbiosis, systemic recursion, and pulsation. We have seen that symbiosis is different from compositions that are not separation-sensitive. Usually, systems that are not separation-sensitive are considered as modular also in the case of interdependency. In modular interdependent systems, the parts, when separated, preserve their essential properties. This is not the case for symbiotic parts of a symbiotic system.

We have also seen that recursive systems are different from systems that allow linear-like, tree-like or network-like representation.

It is somewhat obvious that the paradigm of pulsation is different from what is understood as a process of evolution that tends to preserve only the strongest ‘individuals.’ A similar kind of evolution can be recognized in self-organized systems. Edward de Bono (de Bono, 1992), one of the recognized experts of practically exploitable creativity and innovation, has characterized such a self-organizing system by the fact that “an idea may be logical and even obvious in hindsight but invisible to logic” of externally organized systems. Conversely, in externally organized systems, any idea which is logical in hindsight must be accessible to logic in the first place. This last assertion is true for the classical systems but not for our SRPR systems. Pulsative systems are externally organized by human creators and developers. However, in pulsative systems, no conceptual switch can be considered as logical in hindsight. This follows from the fact that the axiom (or system of axioms) A_{i+1} that extends a theory T_i is logically independent of the previously constructed theories. In consequence, A_{i+1} cannot be logically explained in T_i.

Moreover, the main problem of the pulsation is that of construction and completion-like procedures. The decision procedures are secondary and dependent on the construction and completion-like procedures. In pulsation, all ‘individuals’ collaborate symbiotically towards one goal that is informally specified from the start.

This means that SRPS are complementary to non-recursive systems that are usually considered in Science or business. When compared to such non-recursive systems, a careful study of SRPS and their construction (or development) shows that the research performed in the creation of SRPS requires accepting and developing new relevant ways of evaluation and management. Therefore, in Section 1.6.1, we shall illustrate-by a simple example-why the standard methods of evaluation and management are not relevant to SRPS. Then, in Section 1.6.2, we shall introduce a terminology that will enable us to distinguish between the standard paradigm of systemic construction (or development) and the paradigm relevant to SRPS. The differences presented will justify a need to develop evaluation criteria and management techniques that are relevant to SRPS.

1.6.1 AN EXTERNAL OBSERVATION IS NOT RELEVANT TO SRPS

The next example points out that a widely spread interpretation of the relativity of truth is incorrect and has harmful consequences when this interpretation is applied to SRPS.

In 2005, Science et Vie Junior (2005), an article reports the following experiment. Two nearly placed rockets take off simultaneously. They are observed by a pedestrian and a pilot in a plane flying with a near-light speed. While the pedestrian infers the simultaneity of taking off, the pilot infers that one rocket takes off sooner than the other one. The article concludes that, by Einstein, they are both right.

This illustrates that 'truth' is now understood as a simple result of external observations, which, if we dare say, is not 'true.'

In the context of management, the same understanding of 'relativity of truth' as a simple external observation can be found in the work of Steven Covey, one of the experts of modern management. Indeed in 1999, Steven Covey claimed that a group of people, while viewing that illusory figure, rightly to their perceptions that was either a young or old woman, or both. We have explained above that this picture represents a symbiosis of two 'parts' that cannot exist one without the other. In the context of security, opinions of the two groups mentioned by Covey may lead to an irrecoverable break-down of a symbiotic system.

Since simultaneity is related to symbiosis in the sense that symbiotic parts need to be created all at the same time, we shall illustrate a somewhat harmful character of the standard interpretation of relativity of truth on an example from the medical environment.

Let us imagine that "young girl-old woman illusion" (Weisstein, 2021) is a representation of a surgical technology consisting of two symbiotic parts. Let us suppose that the essential roles of these two parts are as follows. One part ensures the main core of a problem (for instance, eliminating pain or paralysis). The other part ensures that no secondary effects are propagated (thus, for instance, ensuring longevity). Let us suppose that two different surgeons have seen in the symbiotic technology only one of the symbiotic parts. One learns how to eliminate the main core of the problem, while the second one learns how to extend longevity. Both are convinced that they have learned the correct one, i.e., the symbiotic technology. Since, moreover, by the standard interpretation of truth relativity, they are both right, it is not important for patients which of two surgeons is operating them, even though the results of two surgeries are different. In one case, one will guarantee relative health but may provide a short life. The other one will guarantee, for instance, a long life of paralysis. It seems obvious that in such a case, we would all like to have a surgeon that is an expert in symbiotic technology.

The previous examples illustrate that, among all the possible referential systems (or, what is called usually 'point of view'), there is a particular referential system that is the only one that should count when SRPS is concerned.

This particular referential system is that of its creation. We shall call it a creational referential system. Only working in the creational referential system of an SRPS guarantees that, after its creation, the system can be reproduced (thus understood) as an identical copy or 'clone.'

In order to distinguish between the standard interpretation of relative truth that seems to claim the validity of all referential systems ('they are all right') and the interpretation that focalizes on the creational referential system, we shall speak of the Newtonian approach and Cartesian Intuitionism. The Newtonian approach covers external points of view, and Cartesian Intuitionism covers creational reference systems. In the following section, we shall present a motivation for this new terminology.

1.6.2 NEWTONIAN AND CARTESIAN WAY OF CONCEPTION NEW SYSTEMS

The main difference between Newtonian and Cartesian paradigms is easily perceptible from comments pronounced by Newton and Descartes themselves.

In a letter to Robert Hooke, Newton wrote: "If I have seen further (than you and Descartes) it is by standing upon the shoulders of Giants."

Newtonian Science can be seen as established on the logic of sequential 'observational' research. In a little more systemic way, we can thus describe the Newtonian way by a sequence of advancements built one upon the other from a 'beginning' until an 'end.'

We say that this research is observational since, at each step of advancement, it does not require that the previous results are fully recreated. They are only observed externally and adopted as true. This is a model of what means "standing upon the shoulders of Giants."

Descartes wrote his first rule in the *discourse on the method of rightly conducting the reason, and seeking truth in the sciences* (Descartes, 1988) in the following way: "The first was never to accept anything for true which I did not obviously know to be such; that is to say, carefully to avoid precipitancy and prejudice, and to comprise nothing more in my judgment than what was presented to my mind so clearly and distinctly as to exclude all ground of doubt."

This formulation could be looked upon as being similar to Newton's except that Newton expresses the utmost confidence in the 'giants' while Descartes wants to check, or rather to re-create everything by himself before accepting new knowledge. Indeed, Descartes always recreated all the knowledge useful to him when it had been previously obtained by someone else. This means that, if ever standing on 'giants' shoulders' took place, it had to be very carefully checked in order to justify any extension of it.

Descartes justifies these possible extensions by stating that they have to lead to some obvious truth obtained by what he called 'intuition.' He describes what this 'intuition' is in his *rules for the direction of the mind* (Descartes, 1996). When examining his definition from a recursive systemic point of view, we get hints that intuition, for Descartes, is a symbiotic, possibly recursive, composition. The process by which these hints are shown to be reasonable is complex and explained in detail (Franova, 2008). This enables us to use a working hypothesis that Cartesian Intuitionism (Franova, 2014) is based on the logic of recursive creational research.

The same thing is expressed by Descartes in a little more complicated way by saying that "beginnings … can be persuaded well only by the knowledge of all the things that follow later; and that these things which follow cannot be well understood, if we do not remember all those that precede them" (Descartes, 1988: p. 797). From a more formal systemic point of view, we may state that the demarcation of a notion is not the initial stage, as it is the case in the Newtonian paradigm, but the final stage of its formation.

This recursive loop is illustrated in the above process of our formalization of the infinite system of blocks SB.

We thus see that Descartes' work, as we present it, contains a basis of systemic research for SRPS. We introduce, therefore, Cartesian intuitionism as a paradigm complementary to the Newtonian one. For us, Cartesian Intuitionism is nothing but a systemic science relevant to SRPS.

From the point of view of the evaluation and management of a creational process of particular SRPS, it is clear that the notions of clarity and delegation are incomparably more complex in Cartesian Intuitionism than in the Newtonian approach.

1.7 A PULSATIVE TECHNOLOGICAL VISION

In the previous parts, we have introduced the basic notions for rough understanding SRPS. Further work is necessary to provide a deep understanding. As we have illustrated above in Section 1.6.1, SRPS cannot be well understood externally. It is necessary to study them in the framework of a concrete creational referential system. In Computer Science, automation of the synthesis of recursive programs in incomplete domains via inductive theorem proving, i.e., program synthesis is incomplete domains via inductive theorem proving (PSIDITP), provides an experimental creational referential system already now. A formalization of this problem, as well as a description of one particular approach built on the systemic Science of SRPS (Franova, 2014).

In the long term, and expected success of the mentioned approach to PSIDITP provides fundamentals for a pulsative technological vision that may roughly be described by three contributions of PSIDITP. Indeed, PSIDITP seems to be a way how robots, in the future, will be able to:

- Formalize recursively unknown domains (e.g., in space research) handling perfectly control, rigor, and evolutive improvement;
- Perform experiments necessary for finding such suitable formalizations;
- Program themselves autonomously with the help of the formalizations found.

Of course, a successful achievement of this technological vision will require other tools than the ones of the existing approach (Franova, 2014; Franova and Kodratoff, 2016). Necessary will be also the tools developed in machine learning (ML), big data, computational creativity, and some other maybe not yet known scientific fields that will become known in the course of research in PSIDITP and 'pluridisciplinary' cooperation of already existing relevant scientific domains.

1.8 CONCLUSION

In this chapter, we have pointed out the main features of symbiotic recursive systems. These features illustrate the rich potential of SRPS for innovation in various domains that need to handle evolutive improvement, prevention, and control. We have shown that, due to their symbiotic nature, systemic recursion and pulsation can handle incompleteness in the environment of the intended systems. A drawback of our approach is that classical evaluation methods based on external observation are not suited for understanding or for evaluating the creational process of a particular symbiotic recursive pulsative system. This means that a possible extension of the innovation process due to these systems is hampered if we stick to what has been above called Newtonian criteria. The present chapter hints at the necessity of developing new criteria of evaluation and management within the research on concrete pragmatically useful SRPS. These new criteria need to be developed taking into account the main specificities of SRPS and the above-defined Cartesian Intuitionism in the context of a 'creational referential system.'

The present chapter presents a comprehensive introduction to SRPS. Nevertheless, from the evaluation and management points of view of such systems, we have much more underlined the essential problems raised by SRPS rather than solved them. In the future, tackling these problems will demand the co-working of SRPS experts together with specialists in leadership and management.

In the present text, we have presented and illustrated two new ideas in the Science of systems, the ones of symbiosis and pulsation. We have drawn the limits of these ideas as compared to the classical ones of synergy and modification.

KEYWORDS

- **big data**
- **Cartesian intuitionism**
- **computational technologies**
- **inductive theorem**
- **perfect women**
- **symbiotic recursive pulsative systems**

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CHAPTER 2

COGNITIVE COMPUTING: QUO VADIS?

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Consciousness is the mere surface of our mind, and of this, as of the globe, we do not know the interior, but only the crust.

—Arthur Schopenhauer

An important stage of human thought will have been reached when the physiological and the psychological, the objective and the subjective, are actually united.

—Ivan Pavlov

Cutting huge chunks from the cortex doesn't disrupt consciousness, but only changes its contents.

—Michael S. Gazzaniga

ABSTRACT

Progress of AI R&D and applications depends on embedding insights, methods, and technologies from different fields of science. Cognitive sciences and neuropsychology convert the qualitative aspects of being a human-our way to reason and learn, our emotions, language, subjective beliefs, and dynamic personality aspects-into something quantitative and sought after in machine learning (ML) and AI. Still, human cognition is not understood well enough to get translated into algorithms and computational hardware architecture.

This paper aims at describing how cognitive sciences and neuroscience influence AI evolution, what are the current promises and bottlenecks of cognitive computing (CC), and what kind of risks in nascent artificial

intelligence (AI) can be mitigated with the help of cognitive science approaches. The author reviews some companies betting on CC and sketches a prognosis of what to expect in the next few years.

The paper is structured in three parts. Firstly, the author deals with issues around definitions of AI and CC, sketching current technology problems leading to transparency, the accuracy of models' outcomes, and confirmation bias. She raises issues on AI implementation and the hype generated by some providers, which might push research and development of AI and Cognitive technology into the next "AI winter" and therewith increasing risks of cyber-crime and privacy erosion. In the second part, the author talks about brain modularity and brain vs. mind concepts, influencing how AI and cognitive technologies are being built. In the third part, she provides a realistic outlook for CC and talks about the possibility of a quantum future.

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2.1 DEFINITIONS

2.1.1 ARTIFICIAL INTELLIGENCE (AI)

The idea of the brain as a machine was born centuries ago. The brain is a structure of specialized areas, working in close interdependence and governed by physical and chemical forces. Are mind and consciousness products of a brain? What is the role of the nervous system in the creation and functioning of a mind? Different scientific areas-including psychology, physics, philosophy, linguistics, cognitive science and computer engineering-contribute to our understanding of human cognition. We learn how our thinking process is influenced by external (environmental) and internal (body-related) factors. Science also considers the role of emotions in human decision making and problem solving. Besides, the nature versus nurture debate remains one of the oldest philosophical issues within psychology. Nature refers to all of the genes and hereditary factors influencing who we are, and nurture implies all the environmental variables impacting our development, from early childhood experiences to our social relationships and surrounding culture. One isolated scientific field cannot cover everything. Truth can be hidden on borderlines of disciplines. Increasingly, scientific progress is brought about by collaboration, for example between biotechnology and computer-assisted engineering. While we still learn about human consciousness, we have already started to explore the possibility of smart machines. The quest for artificial intelligence (AI) might contribute to our ability to comprehend the world around us, and the role of our species in it. It helps us to assess what life is all about, even if biologists and physicist might never be capable to agree on a common definition.

Max Tegmark, MIT professor of physics and AI researcher, defines life as information processing. Organic and inorganic creations consist of atoms and molecules. Differences between, e.g., a fruit and a human being are however profound: there is no software organizing molecules and atoms in a fruit. In humans, such software enables learning, memorizing, and acting in line with processed information. In the past, humans were capable of building tools for daily tasks-reaching for food, hunting, making clothes and toothpicks. Today, scientists try to develop machines with self-learning capabilities. Tegmark believes that once such machines start building their 'peers,' self-optimize and make independent decisions, a new life form will emerge. Self-upgrading and learning software will enable machines to optimize their own hardware. The scientist calls this phenomenon "Life 3.0." It is unclear whether such life form will peacefully coexist with our own.

Stephen Hawking, the renowned physicist who died in March 2018, was not sure an advanced AI will benefit humanity, unless there are restrictions in place to control how quickly it evolves. Humans have limitations imposed by slow biological evolution. They will not be capable to compete and thrive, if the impact of AI is not carefully planned, from the workplace to the military. Hawking expressed concerns about weapon systems that might eliminate humanity, if they choose.

Elon Musk, the prominent technology entrepreneur, has been worried for quite some time, that AI might be more dangerous than nuclear weapons, or even become an immortal dictator. He created OpenAI as a non-profit research company, enacting the path to safe and beneficial General AI. Of course, the whole concept of 'beneficial' might trouble us, unless we fully understand who decides on what it implies, and why.

Tegmark co-founded The Future of Life Institute, dedicated to risks, ethics, and scenarios around AI technologies. As long as humans think critically about design decisions in AI hardware and software, there will be time to ensure a positive future enhanced by AI. In any case, this AI will be very different from what we know about mammal (including human) intelligence. From today's point of view, computer scientists are struggling to mirror primate ways to guess, solve problems, recognize objects and emotions. Scientists however, implement different definition of what AI actually means. Mimicking human thoughts and behavior is one concept.

Servicing humans-without necessarily by thinking like them-is another one. There is no commonly accepted description on what kind of concepts and ideas contribute to the term “artificial intelligence (AI).”

Mimicking primate- and especially human-intelligence is immensely difficult. No one study on the brain is definitive. It takes a lot of time to go through sometimes conflicting and inconsistent findings to identify the brain processes necessary for intelligence. We still learn about building blocks of what we call mind, consciousness, and intelligence. Difficult questions cannot be kept to the boundaries of just one discipline. We are only in the early stages of this journey.

Let us first consider what schools of AI get inspiration mostly from the primate brain, and how they fit into the broader AI concept.

2.1.2 COGNITIVE COMPUTING (CC) WITHIN AI

The Oxford Dictionary defines cognition as the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses.

Cognitive computing (CC) is a subset of AI using the approaches and algorithms that have been inspired by current and past knowledge of how primate brains work. Advances in evolutionary psychology contributed to our scientific understanding of learning processes. As an example, if we consider how a child thinks, he starts by learning nouns and verbs. To use the language of AI, children are using unsupervised or reinforcement learning (RL) methods.

Not every AI technology is inspired by the functions and architecture of a brain. Principal component analysis (PCA), as an example, is an approach in unsupervised learning, often used for dimensionality reduction and feature extraction. It is not in any way brain-inspired. Olshausen and Field approach to unsupervised learning is closer to being brain-inspired, so it may or may not be considered CC. There are many examples of cognitive-inspired algorithms, e.g., Fukushima’s neocognitron, Carpenter’s and Grossberg’s adaptive resonance theory (ART) and its variants, Jeff Hawkins’ hierarchical temporal memory (HTM) with a large community around startup Numenta, Ballard’s and Rao’s Predictor, Wiskott, and Sejnowski Slow Feature Analysis. The boundaries between CC and other AI technologies are blurred indeed.

Machine learning (ML) is also a subset of AI. Learning is the process of acquiring new, or modifying existing, knowledge, behaviors, skills, values, or preferences. ML implies computer systems can learn from data. As an example, a ML system can be trained on messaging data to distinguish between spam and genuine messages.

Not all AI technologies are based on learning, some (e.g., expert systems or search engines) have no real capacity to learn and modify themselves. Not all AI instances are ML instances. Yet, whenever the machine does learn it is an AI, so any ML instance is an AI instance.

Learning can come in various forms. In the simplest cases it is little more than data accumulation and aggregation (e.g., the k-nearest neighbors algorithm (KNN)). In slightly more advanced cases, the instantiated model parameters (such as connection weights or decision trees) are modified during learning, but the algorithm (the learning rules and their implementation) stays fixed. In even more advanced cases the learning not only modifies the model parameters but may modify the algorithm itself or even the underlying hardware.

The human or primate brain implements all of the learning forms mentioned above. On the shortest time scale, the working memory is simply represented in the level of neuronal activity, as well as reversible short-term changes (facilitation and depression) in synaptic connection strengths. On the somewhat longer timescales, the synapses get strengthened and weakened as a result of the past activity. There is a complex cascade of biochemical processes giving rise to various memory modalities and time scales in the brain, from seconds to decades. Finally, changing environment, body state, values, goals, tasks, etc., result in individual neurons or whole-brain regions being "recruited" or repurposed to new "duties" or sensory and motor tasks.

CC uses the human- or primate-brain approach to problem solving, though this approach is a mystery of its own. Micah Richert and Dimitry Fisher developed some ideas for sensory information processing. Very little research tackles decision making and long-term memory modalities. This does not prevent IBM or NVIDIA from making completely outlandish claims about their cognitive technologies. This marketing has little to do with real progress. True cognition mirrored in silicon and software is still beyond reach. The field of explainable AI (XAI) has just become one of the top priorities for research facilities and companies. DARPA (Defense Advanced Research Projects Agency) in particular is at the forefront of this field. It wants to understand, appropriately trust, and effectively manage new generations of technologies.

XAI goes hand in hand with work on goal modification and self-modification of smart machines. This is important to reduce the potential risks of artificial systems, which increase with growing autonomy, responsibility, and computing power of machines.

Deep learning (DL) is a subset of ML. It can be visualized as a large feed-forward (multilayer perceptron) network being applied to a classification or regression task. "Large" implies that the number N of network parameters (connection weights) is such that ln(N) >> 1. For a given N you can, of course, make the network-wide and shallow (say, 2-layer), or narrow and deep (say, 20-layer). Deep networks have an advantage over shallow ones in that they can represent more complicated functional mappings (disentangle more complex manifolds), or in other words, subtend a large hypotheses space (a larger domain in Hilbert space of input-output mappings). The difficulty is, however, that the larger is the hypotheses space, the higher is the probability to pick the wrong hypothesis, or (equivalently) the harder it is to train the network. Computational complexity-contributing to lack of transparency on how such models work-is another large issue. Last but not least, reliability of results (deterministic outcome) of some ML methods is not a strength in DL. Key factors in ML research are the speed of the computations and the repeatability of results. Faster computations can boost research efficiency, while repeatability is important for controlling and debugging experiments. For DL training computations is sped up significantly by running on graphical processing units (GPUs). However, this speedup is sometimes at the expense of repeatability (non-deterministic outcomes of DL models).

Therewith end-to-end backpropagation has severe problems, as its creator Geoffrey Hinton has recently pointed out. This technology has become the bread and butter for DL in the last five years largely due to increases in memory and computing power available, as well as the advent of big data. Researchers had discovered that one can employ any computational layer in a solution with the only requirement being that the layer must be differentiable. As Carlos E. Perez explains it in plain words, in the game of 'hotter' and 'colder' the verbal hints made accurately would reflect the distance between the blindfolded player and his objective. But what does "accurately" truly mean, if it cannot be replicated while running the model all over again with a matching outcome?

Brute-force GPUs did not ease the task of DL practitioners. Smarter approaches (involving, for example, unsupervised pre-training of network parts) help mitigate existing bottlenecks to some extent. Also, on many problems (especially real-life ones where data points are time-ordered and not independent, in contrast to toy image- or digit-datasets) recurrent networks can potentially do much better. Still, recurrent networks (especially LSTM-based ones (long-short-term memory)) can subtend such vast hypotheses spaces that their training becomes 1% science and 99% 'magic.'

Last but not least, very few researchers (especially in academia) can resist the temptation of reusing the same dataset (or even the same train-test splits) over and over again and picking networks that perform better and better. This is equivalent to training on the test set, as Domingos has long ago very eloquently warned. The result is deterministically non-generalizing (and often non-reproducible) nonsense, contributing to confirmation bias. This is not just an issue of models not working in a lab environment. Confirmation bias damages the reputation of technologies, and it reduces the willingness of traditional companies to experiment and invest.

Datasets are key to any AI technology. CC should (theoretically) handle conceptual/symbolic data, not just labeled data or information from sensors or other devices (edge points). Academic ML deals with structured and labeled data most of the time. Real-life data is most of the time multimodal (or at least multi-channel), often unstructured, and almost always unlabeled. Worse yet, the outcomes (or, in general, value function) is highly nonlocal in time, as today's reward may depend on a decision made a year ago, or on multiple decisions over time, in a highly nonlinear fashion. A question of accuracy, or sensitivity analysis, usually applies around a specific input-output pair; for highly nonlocal (strongly stateful) and/or highly nonlinear problems, the sensitivity analysis is, unfortunately, of limited utility, as it is necessarily local. One has to realize the AI limitations as one realizes the human limitations- and their capabilities. Besides, the inherent challenges in big data in respect of the issues around its volume, velocity of change, value, and veracity should not be forgotten.

While different approaches to learning will keep the next generation of computer scientists busy, one important remark should be made. Cognitive scientists are still only scratching the surface to learn what makes human brains truly unique. As an example, while they compare how human children or chimpanzees are imitating certain behaviors, and how these imitations result in learning. While children imitate all actions that they are shown to attain a reward goal, even the superfluous ones, chimps imitate only the necessary ones. It has been suggested that this indicates that children are compulsive imitators, whereas chimps imitate to attain a goal (similar to what some smart machines do). If a chimpanzee is not presented with a reward (or punishment), however, then the learned behavior is generally not repeated. In contrast, infants will mimic behaviors regardless of whether there is a reward or punishment, suggesting that human infants have a propensity to learn new behaviors for the sake of learning alone. Animals do not demonstrate "l'art pour l'art" activities. Humans-even very young ones-excel in them.

As stated in "The AI imperative: A Practical Roadmap for Business" AI researchers and practitioners might need to wait for universal quantum computing, before a real progress in AI can be made. Definition of a reward function in a quantum environment might be an interesting problem to look at. Can a machine learn just for fun? The response will hardly stay within computer science only.

Today researchers and practitioners should benefit from public interest for AI, and the large investments flowing into the field. There will be myriads of smart narrow-focused AI services and applications, reading medical X-ray images, answering customer questions within a financial planning app, or making predictions on stock development. We should hope that computer engineers look into neurobiology and cognitive science to get a better understanding on the functioning of primate intelligence, brain architecture, and links between a brain and a mind. A better understanding of biological structures and processes might lead to innovation in engineering, creating a multi-tasking AI.

Cutting AI investments and putting the AI industry into the next "AI winter" is not a viable option. ML and CC do not cease to exist. They will be leveraged by cybercriminals for identity theft. Technology companies-without careful considerations on AI risks and ethics-will further contribute to the erosion of privacy. Rogue states with AI in their hands could destabilize current geopolitics to an unprecedented extent.

2.2 INFLUENCING CONCEPTS

2.2.1 BRAIN MODULARITY AND NEURAL NETWORKS

From early on, computer scientists designed hardware inspired by brain modularity. The brain's "architectural constraints" – should we use the language of engineers – include energy costs, size, and processing speed. Today we know a lot more about the different parts of the brain. Many insights came from medical practitioners and researchers, who worked with patients suffering from different brain injuries and diseases. As an example, people with a right parietal lobe injury might behave as if the left side of their body did not exist at all. In the "third man" condition, patients feel the presence of a third person although there is no one there. These patients are fully conscious despite these conditions. They just demonstrate the inability to correctly process information and react to their environment like the rest of us.

The behavior of patients suffering from different medical brain disorders calls for a conclusion highly relevant to developing an Artificial Intellect. Separate brain clusters are in charge of distinct functions in an organism and are interconnected. Again, if we apply engineering thinking here, we assume this modularity provides a lot of advantages to keep energy costs down. The human brain is a fascinating system, consuming just 20 W of power, but enabling a healthy individual to function properly.

Neuroscientists agree that intelligence is not centered solely in the frontal lobes. It involves networks distributed across the brain. There is an inverse correlation between brain activity and intelligence test scores. This activity, measured with imaging studies, is determined by glucose metabolic rate.

Midbrain structures are highly involved in producing subjective experiences. The hippocampus is the brain's area essential for image integration; it also allows the conversion of temporary images into permanent ones. A loss of the hippocampus in both cerebral hemispheres disables the formation of and access to long-term memory. The hippocampus is key to contextual awareness, e.g., recognition of a particular image, linking of personal experiences to this image. If it is damaged, there is still generic knowledge and recognition of images, but no recollection of, e.g., unique people or events. As an example, people with damaged hippocampus will correctly recognize an object as a house. They will however have no memories that they actually lived in this house. Alzheimer's disease is a typical manifestation of such damage.

Most of AI work to reconstruct the brain is however focused on the neocortex, which is mostly responsible for cognition, and is organized into columns with six distinct layers, feedback loops running to another brain structure called the thalamus, and a recurring pattern of short-range inhibitory connections and longer-range excitatory ones. The brain processes information in a clearly defined way through the firing of electrical neurons into patterns described as spiking. Precise descriptions of a spiking process have been around since the 1950s, when Alan Hodgkin and Andrew Huxley formalized the mathematical model that best describes it, and for which they received the Nobel Prize in medicine.

Memories are formed through the strengthening of the connections between neurons that fire together, using a biochemical process called long-term potentiation. Mathematical models exist to mirror these processes.

The engineering of neural nets was inspired by work on decoding a brain's visual system and measuring how neurons spike while receiving a signal. A human brain contains more than 80 billion neurons and tens of trillions of synapses.

Still, biological neural networks offer more mysteries than answers. We do not fully understand, for instance, why neurons spike, e.g., when we judge the relative time of arrival of a signal to our two ears to get a direction. We do not fully see how synapses adapt. At present, in most artificial neural nets, researchers just have a timescale for adaptation of the synapses and then a timescale for activation of the neurons. Intermediate timescales of synaptic adaptation are still missing, which might in turn be very important for short-term memory (Jack, 2017).

An important feature of the brain is its plasticity. During infant to adult development, connections in a brain undergo reconfigurations, as axons and dendrites grow like the roots of a plant, abandoning redundant links and establishing new ones (Murray, 2015).

Therewith computation of neural networks has in-born deficits from the start. If we take image recognition as an example, neural networks will 'read' images while running algorithms through individual pixels, making predictions about the content of the whole picture. Signals are moved from one layer to the next by taking the output of the previous layer. This mechanism is similar to the biological firing of neurons. The process filters out noise and retains the most relevant features to ultimately identify the object. Still, if the machine is provided 'distracting' information-e.g., a very large unusual object positioned in a surrounding which has been already correctly identified-the whole process might fail. Unlike humans, machines cannot do a double-take. They cannot generalize at the human level and make judgments on what might be confusing with the whole picture to start again and have a second glance. One recent article described this phenomenon as a confrontation of a computer with an unusual animal in a surrounding-an elephant in the room. The elephant's presence made the machine 'forget' that it has already correctly labeled tables and chairs (Kevin, 2018).

Our lack of understanding of how the brain and the body interact to produce intelligence and consciousness is not limited to software alone. Rodney Brooks created a so-called "subsumption architecture" for robotics, which replicated the layers of a brain. New information was added to stored information or knowledge and was absorbed or "subsumed' by the system without disturbances. Challenges to add more and more layers in an efficient way were linked to environmental influences. Theoretically, with perfect implementation, such a layered architecture guaranteed easiness to locate a source of error, repair it or change it completely. Primate brains do not allow for such easiness.

Adaptable and biologically inspired automation is a path several ML and CC schools of thoughts will take. Robotic applications will require adaptability to an environment to survive. This intelligence does not require replicating some level of human intelligence. Many biological life forms we know possess incredible intelligence, survive, and are nothing like humans. Carlos E. Perez might be right to say that DL is a good starting point to achieve such biologically inspired machines. These machines will not provide full transparency into their design, goals, and adaptability mechanisms. This branch of DL will be less controllable and thus the possible harbinger of a more dangerous kind of AI (Carloz, 2017).

Furthermore, computer scientists would need to address parts of the brain beyond the neocortex. RL 'mirrors' interactions between the midbrain, the limbic system and the neocortex. RL is useful, especially when dealing with temporal credit assignment problems or delayed-reward problems in not-too-complex state spaces. It is harder to apply in real life than in artificial, simulated environments, but there is a lot of work in that direction (e.g., at Google DeepMind).

For the hippocampus specifically, there are several disjoint lines of research concerning its role in navigation (especially in rodents), memory (especially episodic memory) formation and consolidation. There is a lot of research into what it is that the hippocampus and some surrounding areas are actually doing, but it is not at the level where it can inform some new computational algorithms yet.

Hopfield networks (1982) have been compared in literature to hippocampal CA3 locally interconnected networks. Originally his paper talks about content-addressable memory and physics-based models. The model ("Hopfield network") is essentially a spin glass model, and John Hopfield himself is a prominent physicist, pushing the boundaries between physics and biological sciences. Most probably, Hopfield did not intend it as a model of the hippocampus, but rather as a model of content-addressable (associative, or auto-associative) memory network.

There are a lot of very interesting studies on invertebrates, as their decision-making is more straightforward. These may be applicable in robotics, where simple, fast, robust-to-perturbations responses are often the key. Qualcomm built a wasp eye in its labs without having called it CC. At the end, it was not about mimicking an organ of a primate.

In a broader sense of CC, not every study led to an advance in ML/AI. They have just provided some proxies on how various modalities or functionality of the brain may work. There are studies trying to explain the cerebellum function and various sites and modes of cerebellar learning in terms of control theory. There are studies on short-term memory/working memory, and integrator models for sensory comparison and classification. There are also cognitive science models of working memory in general. This research however does not produce new AI algorithms that can be used by machines to solve a real-life problem. Rather, these lines of research mostly try to explain how the brain works, or what goes wrong in certain neuropathological conditions. Still, every piece of research is valuable.

Modeling different brain cells-beyond the tree-like neocortex neurons-and showing how these different cells interact, will further optimize current DL (Canadian Institute for Advanced Research, 2017). In time, computer scientists might be capable to replicate how multiple information processing streams are orchestrated in the neocortex. Neurobiologists have just described the role of pyramidal cells, which receive inputs from and project to distinct targets. It is however unclear how such communication is being regulated. One study, as an example, demonstrates the capabilities of so-called chandelier cells. A candelabra-shaped cell interacts with hundreds of excitatory cells in its neighborhood, "receiving information from some, imparting information to others." So far, the experimental data came from projects with mice. This particular study focused on dense crowds of "excitatory cells celled pyramidal neurons-several hundred of which can connect with a single chandelier cell. Because each chandelier cell may control the firing of hundreds of pyramidal neurons, it has been suggested that they exert a kind of veto power over local excitatory messages" (Jiangteng et al., 2017).

The role of future data scientists may be more like the role of medical practitioners today. Future data scientists will work in large, complex, not completely understood ecosystems where they will make clinical observations, differential diagnoses, and interventions much like the medical practitioners of today. It is to be seen what kind of hardware will arise to support their work.

2.2.2 COGNITIVE INFLUENCES IN HARDWARE

Today's general-purpose computer design arose by the time central processors could be put on a single chip. This architecture is known as the *von Neuman architecture.* General-purpose architecture is nothing like how a human brain works.

CPUs (central processing units), like Intel's Xeon and Xeon Phi for data-center and the Qualcomm Snapdragon for mobile devices, do a great job for relatively simple data like text and JPEG images, but they may struggle to handle high velocity and resolution data coming from devices like 4K video cameras or radar.

Most AI-focused entrepreneurs innovate on Graphics Processing Units. Driven by the quest for better performance for video, graphics, and gaming, GPU was not fit for general-purpose computations but for additions and multiplications on streams of data.

Unlike central processing unit (CPUs) that compute in a sequential fashion, GPUs offer a massively parallel architecture that can handle multiple tasks concurrently. GPUs have hundreds of specialized "cores" (the "brains" of a processor), all working in parallel, whereas CPUs have only a few powerful ones that tackle computing tasks sequentially.

GPUs have high computational precision that is not always needed and suffer memory bandwidth and data throughput issues. This has opened up a market for a new breed of startups and projects within large companies like Google to design and produce silicon specifically for high dimensional ML applications. Improvements in new designs of chipsets include larger memory bandwidth, computation of graphs instead of vectors (for GPUs) or scalars (for CPUs), higher computer density, efficiency, and performance per watt. This enables faster training of models (especially of graphs); energy and data efficiency when making predictions; running AI systems at the edge (IoT sensors); cloud infrastructure as a service; and autonomous vehicles, drones, and robotics (Nathan, 2017).

Another approach is neuromorphic hardware, where the idea is to construct custom hardware that closely resembles the brain. "Conventional digital hardware performs hundreds of binary floating-point arithmetic operations to simulate a few milliseconds of change in a single neuron's membrane potential. This involves thousands of transistors switching events, each of which consumes power (and generates heat). The neuromorphic approach does away with all this digital paraphernalia and uses analog components that behave like the original neuron. The result is more efficient in terms of power consumption" (Shanahan, PoS. 457).

For whole brain emulation, current technology might have to undergo massive changes. Researchers are successfully developing nascent technologies that already look feasible (e.g., DNA barcoding). Completely new technology might emerge as well, e.g., neural nanobots. Today's neuromorphic hardware exists to simulate a small number of neurons, but to be able to do much else, it would have to be scaled up dramatically. Today we see first neuromorphic chips, which still fail to suggest a robust alternative for current AI applications and services.

As an example, IBM's TrueNorth chip provides lots of useful neural network power, minimal power consumption, and a small form factor. This chip consists of networks of neurons, which best mimic biological neurons. Around 4096 processors; each with 256 integrate-and-fire spiking neurons each with 256 inputs-that can compute all 256 neurons 1000 times per second. That performs 2^{28} synaptic operations per second (256 GSPOs). It uses a very small amount of power. The 70 milliwatts taken by the TrueNorth chip is roughly the same as the amount of power needed to send 100 bytes of data over your mobile phone's Wi-Fi. Will this chip enable a lot of practical applications? We do not know yet. Yann LeCun, Director of AI Research at Facebook and Professor at NYU, criticizes the chip as it does not perform as well as GPUs for image processing.

What is needed is a hardware paradigm that would allow Moore's law to continue beyond the limits imposed by physics "such as speed of light, the size of an atom, and the minimal energy required to flip a bit from one state to another" (Shanahan, PoS. 471). This can be theoretically achieved with so-called quantum-dot cellular automata (QDCA). A Quantum dot is a nano-scale semiconductor device that can act like a transistor, switching states very rapidly but using very little power. The practical application of QDCA is decades away, however. In the nearer term, the semiconductor industry is likely to retain conventional processor design, perhaps exploiting 3D stacks of transistors in an effort to prolong Moore's law as opposed to the 2D slices of silicon that are used today, and perhaps abandoning silicon altogether by adoption carbon nanotubes as the medium for constructing smaller, more efficient transistors (Shanahan, PoS. 471, 485).

An important breakthrough in AI can be expected with the development of quantum chipsets. Microsoft, Google, and IBM heavily invest in their quantum efforts. China spends $10.6 billion on a center for quantum technology.

Quantum computing might enable us to address intelligence from different angles at once. Instead of exploring just one path in a maze, we will consider multiple paradigms, contributing to an ability to think and reason. A better understanding of what makes us intelligent will not arise from a sudden scientific discovery, but from our ability to ask better questions and build technology tools supporting our research. The better we understand how different brain modules interact, the closer we are to explain how mind and consciousness are enabled.

2.2.3 MINDS, EMOTIONS, AND BIAS

The brain interacts with other building blocks of an organism, including the nervous system. In this interaction, human experiences, feelings, and memories are being created. Millions of biochemical, hormonal, and electrical processes and impulses are involved in the process.

The mind is not the sole product of a brain. It evolves through interactions between the brain, body, nervous system, is being steered by myriads of physical and chemical processes triggered inside of an organism, and by stimuli outside of it. These processes manage learning, memorization, and memory storage of signals, forecast, and coordinate responses to them. The nervous system contributed to the development of conscious minds capable of feelings and creative intelligence. Feelings result from our brains activities to map and integrate varied external sensory sources, and simultaneously map and integrate internal states. Thinking is often defined as the manipulation of images created by the memorization and processing of signals, linking them to feelings/emotions, repackaging these in images, and manifesting in reasoning and decision making. Memorization implies not chemical modifications happening at the molecular level. They are "temporary modifications occurring in chains of neural circuits… related to elaborate images of every sensory sort, experienced in isolation or as part of the narratives that flow in our minds" (Antonio, 2018). While recalling, minds reconstruct approximation of the original image, using reverse neural pathways, "which operate from code-holding regions and produce effects within the explicit image-making regions, essentially where the images were first assembled. We have called this process retroactivation" (Damasio, 2018).

Feelings and emotions are crucial to classify and qualify images in our minds, labeling them as beautiful or hideous, pleasurable or painful. In machines, such clustering and qualification require substantial learning efforts. Humans benefit from shortcutting such a learning with feelings.

"Feelings are (mental) experiences of certain aspects of the state of life within an organism" (Damasio, 2018). They are routed in hybrid processes which are neither purely neural nor purely bodily and regulate actions of organisms to maximize conditions beneficial for their well-being. Feelings motivate the development of the instruments and practices of cultures. Biases are partly by-products of such developments, e.g., confirmation bias and Hawthorn effects.

Besides, bias arises in part from our memory, which is distorted at every stage. Sometimes false information is added by mistake, misattribution, or making false assumptions on the observed events. In other situation memory is getting influenced by our systems of beliefs, be it around religion and/or societal order, be it around our past views, our ability to interpret our own actions, and our own sense of belonging to one or another group of 'same-minded.' In a sense, bias goes hand-in-hand with evolution of human biology and culture. Hindsight and stereotype biases are currently coded into data sets and algorithms. They enter a courtroom, a job assessment center, a university admission program. The big 'however' is simple. In biology, a variance is not an error. It is desirable as a driver to adapt and adjust. In computing, the best functioning and most precise models are all about standardization and automation.

Machine and DL allow machines to learn certain tasks and therewith augment intelligence, surpassing a human's insight and accuracy in certain domains, and offering the enormous capability to scale and standardize. Learning is an indispensable component of AI. Researchers and practitioners need however, to find new paradigms around how to build algorithms for representation learning. This is important as Machine and DL has limitations. Their central paradigm is to minimize the so-called objective function. Today it is done through gradient-based method (like stochastic gradient descent where the gradient is computed with backpropagation). According to LeCun, ML machines have to be biased to learn certain tasks (Yann, 2016).

Today we witness a new wave of computing on the edge, emphasizing needs to augment and modify goals. The rise of IoT, and the personalization of services on a device will contribute to the development of new algorithms and capabilities to work with smaller data sets. Some of these sensors and devices will try to capture human emotions. Technology companies will invest in sentiment analysis and emotion tracking capabilities. Currently, they are mostly influenced by so-called essentialism, formulated by Charles Darwin in "The Expression of the Emotions in Man and Animals" (1872).

According to Darwin, each emotion possesses a specific 'fingerprint' caused by ancient parts of the human nervous system. He talks about essence of an emotion. Emotional essentialism is still very widespread with cognitive scientists. The neuroscientist Jaak Panksepp, as an example, believes that an emotion's essence is a circuit in the subcortical regions of our brain. The evolutionary psychologist Steven Pinker compares emotions and mental organs, similar to body organs for specific functions. Paul Ekman, a psychologist, assumes that essences of fear, surprise, happiness or sadness are triggered by events or objects. In the end, researchers drive to reduce variance in order to build a perfect theory will further encourage bias, which will get automated and scaled by the power of AI.

Though essentialism promises simple, single-cause explanations that reflect common-sense, it remains a proxy. Researchers disagree on the nature of the essences. We continue living in a very complex world, where variance prevails, and standardization just help us to save energy and make decisions faster. It hard to codify emotions into a stable ontology.

While recent studies by Lisa (2017) show that emotions are not universally pre-programmed in our brain and bodies but represent unique experiences of individuals-the variance of influences by individual histories and environments-current CC is just discovering essentialism.

For news stories or ads, it is often a kind of natural selection: agencies figure out which word combinations, hashtags, etc., elicit more clicks, and those get used more often. Natural Language Processing companies such as Symantec utilize psychology research and text analysis to identify patterns of expressing a feeling, describing a sentiment, and defining a wish. Language does offer insights into the state of our mind. Still, reading and translating actual human emotions interactively and in real-time, is really an impossible undertaking today, no matter how much entrepreneurs and application developers praise their technologies. Only partial guessing and interpreting is possible.

Social scientists have found that only up to 10% of the emotional meaning of a message is conveyed through words. About 35–40% is conveyed in the tone of voice, and the remaining 50% through facial expressions and bodily gestures (Nicole, 2017).

Affectiva, a spin-off of the MIT Media Lab, collected an emotion database with nearly 6 million faces from 75 countries, including face videos. There are 38,944 hours of data, representing nearly 2 billion facial frames that were analyzed. The data is global, spanning ages and ethnicities, in a variety of contexts and situations (e.g., people sitting on their couches or people driving a car). Affectiva then applies ML and DL to analyze this data. The company partners with another firm called Brain Power to bring use cases to the market. As an example, Brain Power uses Affectiva technology and Google Glass to help autistic children with emotion recognition and understanding (Becky, 2018).

MIT researchers have developed a robot that uses ML to gauge the engagement of autistic children during therapy sessions. Robots are often used to help autistic kids recognize and respond appropriately to emotions, but these were also equipped with a DL system. The machines were able to detect and analyze the children's facial expressions and reactions.

New York-based Emoshape introduced a chip called EPU II (emotion processing unit). It delivers high-performance machine emotion awareness.

Its founder Patrick Levy-Rosenthal extended Paul Ekman's theory by using not only 20 primary emotions identified in the psycho-evolutionary theory but also pain/pleasure and frustration/satisfaction [Ekman pioneered a study of emotions and their relation to facial expressions, creating an atlas of emotions].

The EPU algorithms enable machines to respond to stimuli in line with one of the twelve primary emotions: anger, fear, sadness, disgust, indifference, regret, surprise, anticipation, trust, confidence, desire, and joy. The emotion recognition classifiers achieve up to 94% accuracy on a conversation. A London-based company called Being More Digital works on capturing real-time human emotions on video and developing predictive models to better understand customer loyalty, satisfaction, or location profile (e.g., for retail).

The Berlin-based startup Musimap SA uses AI to capture human emotions and to build user profiles depending on their music taste. The company has built a large proprietary database for its computation.

It takes people 20–30 years to mature socially, and AIs would be no better off. Targeted advertising does not need this: it shows you what you want to see and tells you what you want to hear. Emotions are much harder: I sometimes cannot even figure out what my 9-year-old and her friends are thinking and feeling. How can I train an AI to do this if I am not capable to clearly describe what I observe and experience? Even further, do I ask the right questions and collect the right data to answer them?

2.3 COGNITIVE SCIENCE AND COGNITIVE COMPUTING (CC): AN OUTLOOK

2.3.1 BRAIN VS. MIND

The attempts to identify one single area of a brain to 'locate' consciousness have so far failed. There is no specific region of the brain in charge of all the aspects of consciousness, including feelings of subjectivity and integration of experiences. Activities of multiple senses (e.g., auditory, and visual systems), brain-stem structures, cerebral cortices, hypothalamus, amygdala, basal forebrain, and insular and cingulate cortices are all involved, in connection with other areas of a body. The coordination of senses, their processing, resulting feelings and building of memories take place in medial cortical regions, e.g., in posteromedial cortices with the assistance of thalamic nuclei.

The idea of consciousness might be just a proxy for a number of variables linked to the mental, intelligent life of humans. Throughout decades scientists used the term to speak about language, perception, and emotions. Some researchers add instincts to a list of the functions of a conscious being. Marvin Minsky-one of the fathers of AI-called it a 'suitcase word,' as it had many different meanings. "Consciousness … is a particular state of mind in which mental images are imbued with subjectivity and experienced in a more or less extensive integrated display" (Damasio, 2018). Consciousness is a "proxy world for how a complex living organism operates" (Michael, 2018).

In 2018, a celebrated brain scientist Michael Gazzaniga made an important hypothesis, which might influence cognitive science and AI like nothing before it. Inspired by physics, he suggested complementarity was the crucial principle in the design of organic and inorganic life. Light can behave as particles and as waves. Maybe we should think about brains and minds in the same way. "Following its acceptance in physics, the idea of complementarity may prove itself to be key to thinking about biology, and about the mind/brain gap in particular" (Gazzanica, 2018).

Quantum computing capabilities will add granularity in our understanding of brains and minds. We will be able to observe the universe algorithmically, rather than having to model it first. Infinite increase in variance represents a path very different from current standardization and automation. A future based on variance appears to be much more desirable from commonly accepted descriptions of an AI apocalypse. R&D facilities and entrepreneurs will require investments and freedom to experiment. Overhyping current cognitive technology-along with overall AI capabilities-might hurt the industry and damage our prospects for the future we want to live in.

2.3.2 REALITY VS. HYPE: A WORD OF CAUTION

Investments in CC research and development will largely depend on what direction the current hype around AI will take. Some businesses might lose interest to AI technologies without capturing any benefits for them. This might happen in companies unable to understand the value of data to improve the top and bottom line. On the other hand, many AI applications will move mainstream: OCR, NLP, fraud detection, anomaly detection, facial recognition (scaled in countries with authoritarian regimes), targeted marketing and advertising, high-frequency trading, warehouse automation, limited autonomous driving features for passenger vehicles, trucks, and service robots, haptic learning and imitation in robotics. Once the hype is over, many consulting services will fade, especially for people who did not gain any knowledge beyond a Coursera or Udacity ML course. There might be backlashes too. On another more sober note, good teams and companies telling the truth about AI limitations might lose funding and industrial support. They cannot compete with the hot-air balloons of marketing and hype.

CC in the age of new AI realism (I do not want to call it a new "AI winter") might still be indispensable in the predictive analytics and targeted advertising. It might gain a broader impact on political life. Right now, according to estimates, Google controls about 2% of the votes in US presidential elections. This number might easily climb to 20% by 2020. People are surprisingly similar to Niko Tinbergen's geese: give it a supersized fake egg and it will forget about its real ones. Give people something that fits incredibly well with their worldview and you can feed them all sorts of lies or make them do whatever you like. The industry of generating these tailor-made supernormal stimuli for advertising, journalism, and politics will grow in leaps and bounds.

Another viable field in CC will remain healthcare. Even if the stock markets will go down precipitously, healthcare will not stop looking for ways to improve itself. The population in Western democracies will not get any younger on average. Individual medicine and drug discovery will shift gradually towards different types of AI. Care automation will continue to develop to reduce waiting time and optimize patients' referrals. New solutions will continue to evolve in diagnostics, data collection and aggregation. At-home diagnostics will further progress, and so AI-enhanced drug discovery.

A very prominent example might be autonomous cars. Most implementations are cognitive in nature. They learn by example and improve over time by observing a driver's behavior.

Last but not least, CC will continue to progress in entertainment, especially in hyper-realistic computer games. Second Life type of environments might get reinvented to feed reality escapism of people. Crops never fail, pets never die, food never spoils. Why not just move into a computer game entirely?

Companies such as IBM claim this technology can process and derive insights from a huge amount of data to provide humans with decision making support. CC is inherently probabilistic, which means it cannot offer 100% precision or completely accurate answers. Raising the accuracy of these systems means to train them specifically for one application in one sector. This implies mounting cost due to the time of customer personnel involved in training.

A word of caution seems to be in order here. Today's CC is over-hyped by vendors. I talked about IBM and other vendors jumping on AI and CC bandwagon in "The AI imperative. A practical roadmap for business" (2018). The gap between technology and marketing is wide. While top Technology Players are starting to create Ethical Advisory Boards to address AI technologies within their companies, they might want to consider whether capitalizing on insufficient knowledge about data, AI, and CC at their enterprise customers might backfire not just at their reputation. It damages prospects of how we make progress as societies or even humanity.

The AI agenda will always fall short, unless researchers, policymakers, entrepreneurs, and leaders of top technology brands develop frameworks beyond traditional automation and augmentation. Contemporary cognitive science makes us think about the desirability of variance, complexity, and diversity. Norms should not be mistaken for mathematical averages, even if we already know how to build them.

KEYWORDS

- **adaptive resonance theory**
- **artificial intelligence**
- **cognitive computing**
- **deep learning**
- **graphical processing units**
- **hierarchical temporal memory**
- **k-nearest neighbors' algorithm**

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CHAPTER 3

DIGITAL TRANSFORMATIONS IMPERATIVES: PREDICTIVE GOAL PROCESSES FOR BUSINESS MODEL INNOVATION

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ABSTRACT

The business modeling (BM) concept is viewed as characterized by system functions on predictive modeling schemes with prioritized strategic decision systems. Value creation optimizations are considered that are applied to enterprise modeling with new techniques for business mapping to business processes to prove viability. Though we are not alone on the economics ecosystems BM process, the systems modeling with structural processes that we invoke are novel concepts that are more concrete techniques for reflecting BMs as categorical functions on business process diagrams for EM optimization on economics eco parameters, with morphic reflections on infrastructures, permeated by BM innovations, data-driven decisions on value measures, with direct impact applicability for how a company implements a profitable strategy creating value for both the customer and the enterprise. The areas explored range from plan goal decision tree satisfiability with competitive BMs, to predictive analytics models that accomplish goals based on business logic and business processes. Our processes for digitization

value creation impacts and AI digitization management strategy areas are previewed. Value creation optimization and dependencies are presented with a startup example.

3.1 INTRODUCTION

The purpose of this research paper on business model (BM) variances and enterprise competitive goals is to substantiate what will be the important factors for businesses' sustainability and profitability and why to invest in the developments. The concept of BM is examined to consider how different enterprises develop, for example, as a platform for resources, processes, etc., that together are creating value for a company. Further, a BM cannot be a static concept but must embed implicit control loops for sustainability purposes. The paper addresses the following:

- What is the background. Theoretical gap?
- What will be the theoretical and practical contributions from this paper?
- How this brief is the direction for accomplishing the goals.

The above goals are accomplished by accommodating BM innovation while optimizing existing resources, infrastructure, EM revisions, based on predictive analytics, ecosystem morphology techniques, and driven decision on digitized management business processes. In particular, we present a systems categorical view towards realizing BMs on business processes that accomplish the BM goals on a structural mapping basis.

3.1.1 METHODOLOGY

The method we started with are based on a search on the keyword: 'BM' to find where to start addressing the relevant questions concerning what the contemporary business schools. Further, we searched for the interest areas on the leading database in the fields search strings BM, economics, AI digitization, enterprise modeling, and management science, management information systems, or innovations on BMs management. We have chosen our pivot points on what we find sound and compatible with our structural views to move forward with. Since September 2019 motivated by funding proposition goals, over 200 articles on BM and BM value creation economics ecosystems were examined and 10 papers were selected that looked more promising and relevant to our thoughts and goals to consider for discussions that support our directions, while the first author since some years published or edited volumes on the field (e.g., Nourani, 2017, 2018).

Technically our methods are analytic scientific, which means that we take a structural view to what a BM so that the structure and its variations created by innovations options can be systematically mapped is to an appropriate characterization for business process models structures, that might allow a better comprehension for innovations on BMs, parametrized with business value creations functions. The first author for this manuscript has over a decade of research published on categorical systems. On very specific application areas, he has devised categorical systems for realizing processes, e.g., business or computing. The Pullback categorical mathematical technique was specifically his contribution towards systematic systems realizations with morphic functions, for example, for business objects structures presented for business processes. The technique has been applied as recently as 2015 to natural language models for business interfaces at TU Berlin, Germany, e.g., summary briefs since posted on the areas at (ResearchGate site Nourani-Projects). That technique is applied to BM realizations in a preliminary format reflecting on the economics ecosystems research and business economics morphology on the papers reviewed since and on the Nourani (2018) edited volume for Apple Academic Press. For these purposes, that might be viewed as mathematical systems dynamics processes. The section on digitization on this manuscript presents more specific methodologies by Dr. Annika Seiber, my coauthor of this manuscript as follows.

Section 3.3 is based on previous research conducted by Steiber and Alänge (2020). This research was focused on how different models for corporate-startup collaboration could support in the digital transformation of a large firm. A framework presented by Venkatraman (1994) was used in order to analyze how each collaboration model has impacted the firm's business transformation. In Section 3.1, the same framework is used to discuss potential value creation as a result of the digitization of firms' BMs as well as business processes. In addition, a literature review was conducted between March and April 2020 focused on search strings such as: 'digitization and value creation'; digitization and effects'; 'digitization and economic value'; 'digitization and innovation'; 'digitization and productivity'; and 'digital transformation and value creation.' Further, the literature review was focused on previous research investigating: 'digitization and value creation and metric,' as well as 'digitization and value creation and measurement.' Over 50 articles and their abstracts were scanned, of which 22 were selected and used in Section 3.1.

3.1.2 FINDINGS

We develop new techniques to accommodate BM innovations based on the economics ecosystem, (Lüdeke-Freund and Gold, 2018; Nourani-Schulte, 2014) on morphic economic models, morphic typology, with our newer structural pull reflections on the existing infrastructure, value creations data-driven decisions and derivatives, on business processes. Content models on infrastructures play a role varying parametrized BM concept is a creative ERP optimization process that applies big data filtering (Nourani, 2016, 2018).

Preliminary data on the available publications referred to, the enterprise systems deployed, e.g., SAS so on and so forth. AI Digitization Management Strategies impact examples of BMW examples that are previewed.

3.1.3 PRACTICAL IMPLICATIONS

Accommodating BM innovation while optimizing EM based on existing resources, infrastructure, personnel retention, or repositioning. The process affords business with systematic business process management sequences for accommodating BM innovations to remain competitive and profitable while retaining near full EM and ERP employment.

3.1.4 THEORETICAL VALUE

Technically our methods are analytic scientific: we are taking a structural view to what a BM is and map that structure and are variations on innovations to business process models structures to realize the innovations on BMs parametrized with business value creation functions. Newer techniques on how that can play on the EM, ERP management, and BMs to be presented on the paper. Because of the circular economy (CE) and typology for ecosystems on the newer directions for BM innovation, while this first author published on morphic structures on economics models since 2014, on the views of the system in this paper, we develop a categorical morphic view to reflecting BMs structures onto business process diagrams models.

To put the areas on the newer current perhaps prominent pragmatics, we review what is rethinking BMs for the CE and ecosystems bases. A good forward to BM's vs the business ecosystems is to follow Luedke-Freund et al. the morphological analysis builds on the consideration that CLSCs and their reverse cycles—as the backbone of the CE—require a large variety of BMs, and that linear business logics based on taking, making, and disposing of resources and goods are not consistent with, or even contradict, CLSCs (Wells and Seitz, 2005). Nearly all companies still apply linear production systems, aiming at maximum economies of scale, optimizing high throughput levels, and using highly standardized one-way designs instead of processes, materials, and products designed for take-back, refurbishing, remanufacturing, recycling, or upcycling (Stahel, 2016; Tong et al., 2018).

Or, as Accenture (2012, 2014) puts it, "…companies today are simply not built to capitalize on the opportunities the CE presents. Their strategies, structures, and operations are deeply rooted in the linear approach to growth …," and therefore companies "need to develop BMs that are free of the constraints of linear thinking." BMs and their innovation are crucial to allow companies to create value through the implementation of CE principles (De Angelis, 2016; EMF et al., 2015; Schulte, 2013; Tong et al., 2018). For example, consider the following paraphrased view: A BM is a conceptual tool containing a set of objects, concepts, and relationships to express the business logic of a specific firm, technical nutrients cycle (Braungart and McDonough, 2007).

An informal view to how a BM can be reuse and redistribution CEBM pattern combined design options, The grey area design options together propose generic reuse and redistribution elements of the composite BM framework resource, value chain, competence, value proposition, distribution channel, customer segment, competitor, partner, and financial structure. BM pattern. The consensus on BM components on the leading publications has resulted in the identification of 10 common BM components: supplier, resource, value chain, competence, value proposition, distribution technical nutrients cycle (Braungart and McDonough, 2012). An informal view of how a BM can be reuse and redistribution CEBM pattern combined.

Our goal is to present very specific systematic processes that can be a real track for accommodating the CE on innovation processes, thereby instantiating that, while reflecting on Nielsen-Lund, onto, e.g., Amit-Zott summary, on how to realize value creation transformation links, how to model value creation with specific structural reflection pullbacks to business process models, e.g., illustrated on BPMN diagrams (Popkit, 2003), or how to optimize on the value creation process. BMs are presented as schemes with inputs-outputs and assets creation depletion objects operations.

Considering typology of circular economy BM pattern: Our morphological analysis builds on the consideration that CLSCs and their reverse cycles—as the backbone of the CE—require a large variety of BMs, and that linear business logics based on taking, making, and disposing of resources and goods are not consistent with, or even contradict, CLSCs (Wells and Seitz, 2005). Nearly all companies still apply linear production systems, aiming at maximum economies of scale, optimizing high throughput levels, and using highly standardized one-way designs instead of processes, materials, and products designed for take-back, refurbishing, remanufacturing, recycling, or upcycling (Stahel, 2016; Tong et al., 2018). More systematic techniques are advocated by (Nielsen-Lund, 2019). While a BM is concerned with the unique combination of attributes that deliver a certain value proposition.

Therefore, a BM is a platform, which enables the strategic choices to become profitable. The BM is thus conceived as a focusing device that mediates between technology development and economic value creation. We argue that firms need to understand the cognitive role of the BM, to commercialize the technology in ways that will allow firms to capture value from their technology. On the important directions for value creation, we examined (Amit and Zott, 2019) for creating value through BM innovation. A company's BM is a system of interconnected and interdependent activities that determines the way the company "does business" with its customers, partners, and vendors. In other words, a BM is a bundle of specific activities—an activity system—conducted to satisfy the perceived needs of the market, along with the specification of which parties (a company or its partners) conduct which activities and how these activities are linked to each other.

The above research surmises that in a highly interconnected world, especially one in which financial resources are scarce, entrepreneurs, and managers must look beyond the product and process and focus on ways to innovate their BM. A fresh BM can create and exploit opportunities for new revenue and profit streams in ways that counteract an aging model that has tied a company into a cycle of declining revenues and pressures on profit margins. We suggest that managers ask themselves the following six key questions as they consider BM innovation (Figure 3.1):

1. What perceived needs can be satisfied through the new model design?
2. What novel activities are needed to satisfy these perceived needs? (BM content innovation).
3. How could the required activities be linked to each other in novel ways? (BM structure innovation).
4. Who should perform each of the activities that are part of the BM? Should it be the company? A partner? The customer? What novel governance arrangements could enable this structure? (BM governance innovation).
5. How is value created through the novel BM for each of the participants?

6. What revenue model fits with the company's BM to appropriate part of the total value it helps create?

FIGURE 3.1 The basic BM process.

The sections are structured as follows: BM areas are presented. Definitions, objectives, and variances. Economics ecosystems, value creation, and systematics overviews are examined. We start with a functional view of a BM and consider the structural options for realizing BMs on business processing structures that can be realistic accommodations, how to instantiate BMs and what are the interdependencies for value creation. Section 3.3 presents the digitization paradigms and examines now digitization and value creation relevant to BM realizations. Section 3.4 presents several examples from realistic business applications, e.g., BMW are reviewed. The value creation process with digitization is analyzed with some hind-sights on IT digitization experiments. Section 3.5 presents our newer categorical systems view on how to realize BMs on business process structures applying structural pullbacks to business process functions that can be reflective of BM innovations. We further examine how to optimize value creation with the above systematic view, while considering an example startup business plan scenario (Nourani, 2005, 2018) that accomplishes BM innovation with a product-market pushout on the BM process to optimize value creation links. Section 3.5 concludes with presenting goal plan accomplishments based on competitive BMs.

3.2 BUSINESS MODEL (BM) DEFINITIONS

Let us start with an overview glimpse based on Betz (2002): A BM is a conceptual tool containing a set of objects, concepts, and relationships to express the business logic of a specific firm, technical nutrients cycle (Braungart and McDonough, 2007). An informal view to how a BM can be reuse and redistribution CEBM pattern combined design options, The grey area design options together propose generic reuse and redistribution elements of the composite BM framework resource, value chain, competence, value proposition, distribution channel, customer segment, competitor, partner, and financial structure. BM pattern. The consensus on BM components on the leading publications has resulted in the identification of 10 common BM components: supplier, resource, value chain, competence, value proposition, distribution channels, customer segment, competitor, partner, and financial structure.

An aggregation for a value network is essential for pragmatizing a BM to ascertain and measure the BM's effectiveness. That entails stating the definitions of customer segments, suppliers, competitors, and partners. Definitions intangible might be constituting concept resources or human skills that can be accommodating the processes. The tangible means, and means under control of an organization by being bought or licensed, which are combined within the value chain of activities. Value chain: The overall business process infrastructure that describes the set of activities, combine resources, to create the necessary competences.

3.2.1 BUSINESS MODELS (BMS) AS A CREATIVE TECHNIQUE

Considering open BM notions (Chesbrough, 2006) topic, the "open BM" has become a frequently used concept in literature. Open BMs are delineated with the value of integrating ideas, knowledge, and resources from external partners into the BM of the focal firm. Research on open BMs is still new and researchers so far have primarily focused on the benefits of open BMs (Chesbrough, 2007; Davey, Robinson, and Wei, 2012), on developing typologies (Holm, Günzel, and Ulhøi, 2013) Considering Roelens and Poels (2019) the development of the BM concept is a creative problem-solving process, with some bases on the existing publications. In the first phase of this process, divergent thinking has resulted in various interpretations and uses of the BM concept, originating from research such as e-business, strategy, information systems, etc. Newer examples are provided in Alange and Sieber (2019).

Some example directions are: (i) Competence: the ability to coordinate flows of resources through the value chain to realize the intended value proposition; (ii) Distribution channel: the way in which the offering is made available to the customers; (iii) Value proposition: offered a set of products and/or services that provide value to the customers and other partners and compete in the overall value network. (iv) Value network: web of relations created with external stakeholders, including suppliers, customers, competitors, and partners. However, there is a lack of shared opinions about the BM concept between the different integrative views, as there is still no agreement on the common conceptual basis which underlies the concept. Let us move on with rethinking BMs for the CE: the morphological analysis builds on the consideration that CLSCs and their reverse cycles—as the backbone of the CE—require a large variety of BMs, and that straight forward business logics based on taking, making, and disposing of resources and goods are not consistent with, or even contradict, CLSCs (Wells and Seitz, 2005).

Nearly all companies still apply linear production systems, aiming at maximum economies of scale, optimizing high throughput levels, and using highly standardized one-way designs instead of processes, materials, and products designed for take-back, refurbishing, remanufacturing, recycling, or upcycling (Stahel, 2016; Tong et al., 2018). Or, as Accenture (2012, 2014) puts it, "…companies today are simply not built to capitalize on the opportunities the CE presents. Their strategies, structures, and operations are deeply rooted in the linear approach to growth …," and therefore companies "need to develop BMs that are free of the constraints of linear thinking." BMs and their innovation are crucial to allow companies to create value through the implementation of CE principles (De Angelis, 2016; EMF et al., 2015; Schulte, 2013; Tong et al., 2018).

The CE requires companies to rethink their supply chains and BMs. Several frameworks found in the academic and practitioner literature propose circular economy business models (CEBMs) to redefine how companies create value while adhering to CE principles. A review of these frameworks shows that some models are frequently discussed, some are framework-specific, and some use different wording to refer to similar CEBMs, pointing to the need to consolidate the current state of the art. Freund (2019) and Bocken et al. conducts a morphological analysis of 26 current CEBMs from the literature, which includes defining their major BM dimensions and identifying the specific characteristics of these dimensions. Based on this analysis, we identify a broad range of BM design options and propose six major CEBM patterns with the potential to support the closing of resource flows repair and maintenance; reuse and redistribution; refurbishment and remanufacturing; recycling; cascading and repurposing; and organic feedstock BM patterns. We also discuss different design strategies to support the development of these CEBMs. That study compares reuse and redistribution CEBM pattern in the value proposition/services dimension means that this is a primary offering of this BM (B2B = business to business; B2C = business to customer; BM

= business model; C2C = customer to customer; CEBM = circular economy business model).

3.2.2 BUSINESS MODEL (BM) CONCEPTUALIZATION

Here is what some authors view the process: This first stage is a definition of what BMs are and what belongs there, to have meta-models that conceptualize them. On this level, the BM is seen as an abstract concept that allows describing what a business does to earn money. The definitions (Timmers, 1998; Magretta, 2002) simply give an idea of what a BM is, whereas the meta-models (Chesbrough and Rosenbloom, 2000; Hamel, 2000; Linder and Cantrell, 2000; Mahadevan, 2000; Amit and Zott, 2001; Applegate, 2001; Petrovic, et al., 2001) Weill and Vitale addition define what elements are to be found in a BM. Some authors such as Hamel (2000) substantiate the conceptual aspect, while others adopt a rigorous modeling approach (e.g., Osterwalder, 2004).

Gassmann et al. (2019) summarize the realistic open BM status as follows are for the most part firm-centric. More on the typologies of open BMs to structure the field (Holm et al., 2013; Purdy et al., 2012; Sandulli and Chesbrough, 2009; Sheets and Crawford, 2012). Others highlight the interdependence between the focal firm's and its partners' BMs, where the BMs of all actors need to be aligned (Berglund and Sandström, 2013; Lindgren, Taran, and Boer, 2010) and a separate value proposition has to be formulated for each partner. The macro view to BMs is summarized on a typology by Lüdeke-Fruend et al. (2018) considering a morphology on the BM in the future.

- Repair and maintenance BMs repair and maintenance models (e.g., building on "repair" (Kiørboe et al., 2015).
- Reuse and redistribution BMs reuse and redistribution models (e.g., building on "reuse/refurbish/maintain/redistribute/next- life sales" (Planing 2015), "reuse" (Kiørboe et al., 2015), and "product life extension" (Accenture, 2014).
- Refurbishment and remanufacturing BMs refurbishment and remanufacturing models (e.g., building on "remanufacturing/next-life sales" (Clinton and Whisnant, 2014), "upgrading" (Planing, 2015), and "product life extension" (Accenture, 2014).
- Recycling BMs recycling models (e.g., building on "closed-loop production," "dematerialization" (Clinton and Whisnant, 2014), and "recycling and waste management" (Kiørboe et al., 2015).

- Cascading and repurposing BMs cascading models (e.g., building on "multiple cash flows/multiple revenues" (Pauli, 2010) and "co-product generation from waste" (Albino and Fraccascia, 2015) are inspired by the ecological principle dubbed "waste is food" by Braungart et al. (2007).
- Organic feedstock BMs once all technically and economically feasible cascades are used, organic residuals can be processed via biomass conversion.

Considering the above, here is a view to a CE on value creation: value perspective on circular economy BMs "value-added" is a typical way to depict the economic value created through BMs and accumulated across supply chains. The "value retained" of a used product, its components, and its materials are not as easy to determine in the current linear economy. BMs that slow resource loops retain the highest product value for as long as possible. BMs that support closed loops seek to retain value at the material level. The cascading models suggested by Braungart et al. (2007) seek to retain material value by iterating multiple uses of the same material. Further application areas are on Thonemann and Schumann (2018).

3.2.3 KNOWLEDGE AND BUSINESS LOGIC VIEWS

This level consists of several types or meta-model types of BMs that are generic but contain common characteristics (Bambury, 1998; Timmers, 1998; Rappa, 2001; Weill and Vitale, 2001). Types refer to a simple categorization, while meta-model types refer to different models. As explained above, this distinction reflects different degrees of conceptualization. Furthermore, the types and models can but are not necessarily a sub-class of an overarching BM concept (Weill and Vitale 200). Also, the BM taxonomies do not necessarily apply to businesses in general but to specific industries, such as to WLAN (Shubar and Lechner, 2004), computing (Rappa, 2004), mobile-games (MacInnes et al., 2002). The standard realistic enterprise BM systems are the multitier layers on business processes, business logic, and interfaces. A presentation layer contains components dealing with user interfaces and user interaction. A business logic layer contains components that work together to solve business problems. These components might be CRM, pure Web, catalog engines, pricing engines. Cooperate memory and KM are applied here. The technical business layer is based on Financials, HR, distribution, etc.

3.2.4 A LANGUAGE FOR DESCRIBING BUSINESS MODEL (BM) STRUCTURES

Let us deploy a schema technique similar to the following example from Nourani (2005): to key onto the incomplete knowledge base, practical AI systems are designed by modeling to AI with facts, rules, goals, strategies, knowledge bases. Patterns, schemas, AI frames, and viewpoints are the micro to aggregate glimpses onto the database, and knowledge bases were masses of data and their relationships-representations, respectively, are stored. From Nourani (2005) the schema for a stock trading platform analytics is as follows:

- An equity trading platform BM;
- IS-An asset management system;
- Business objects: portfolios, stock, bonds, corporate assets;
- Typology: Asset management techniques;
- Schemas allow brief descriptions of business object surface properties with which high-level inference and reasoning with incomplete knowledge can be carried out applying facts and the defined relationships amongst objects.

We will present the above example with the business model modeling languages (BMMLs) to make BM ideas more concrete and comprehensible for analytics. The process by visualizing the business logic and specific elements of a BM is claimed to facilitate tasks (e.g., Osterwalder et al., 2005), generating BM ideas (Chesbrough, 2010), and deducing requirements for the underlying IS (Gordijn and Akkermans, 2003). Moreover, one specific language, the BM canvas, has had a tremendous impact on research and practice: a corresponding book (Osterwalder and Pigneur, 2010).

The realization of a BPMN diagram for business mode instances becomes a generic organization diagram illustrating the process of transforming inputs to outputs in a chain-like fashion. A BPMN diagram for such schemes that can be programmed for a BPML process computing resembles the following for an ERP system (Figure 3.2).

3.2.5 MAPPING TO BUSINESS PROCESS MODELS

Business process models describe how a business works, or more specifically, how they accomplish missions, activities, or tasks (henceforth referred to as tasks). A single module presents how a business accomplishes a single task.

It would take many process models to fully detail the "hows" of most real-world enterprises. A single process might consist of many parties (people, organizations, systems) performing a multitude of tasks. To accomplish a complete task, the parties must complete specified sub-tasks in a coordinated manner. While the sub-tasks can be performed in parallel, sometimes they are required to be sequential. Some processes require the repetition of sub-tasks.

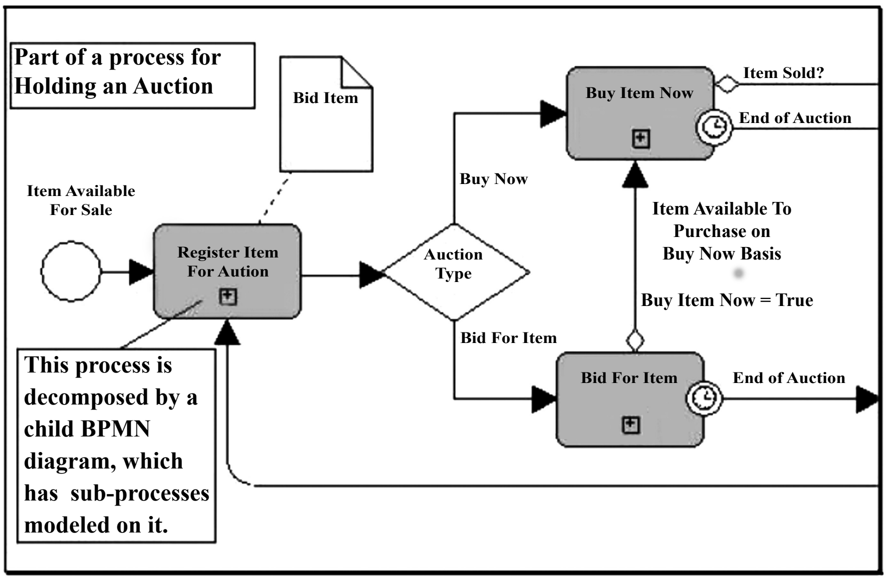

FIGURE 3.2 Auction example BPMN: BPMN manual.

Most processes have decision points where processes branch depending on many parameters, i.e., the condition of the system or the particular process execution. For cooperative processes computing agents must exchange information. The information transfer can be the trigger for an actor to begin a sub-task. Other triggers are possible, such as time or interrupt. Some processes are ad-hoc. That is, the sub-tasks do not have well-defined triggers. Agents may not need to complete all of a subtask before they or another actor start work on another dependent subtask. Finally, a process can have a different template when perceived from the viewpoint of different agents. A business process modeling methodology needs to be able to represent these different aspects of a process description. A good business process model has representations that are easily transferred into the tacit knowledge of the acting agents.

The business process modeling language (BPML) is a "meta-language for the modeling of business processes." BPML provides an abstracted execution model for collaborative and transactional business processes based on the concept of a transactional finite-state machine. The essential feature of BPML is that it has a common public interface and private implementations. The public interface is exposed to business partners to allow the exploitation of the strengths of each separate company in a larger collaborative effort. The essentials managing component agents of the corporation are embedded in the private implementations within the language BPML.

For our BM systems views for morphic functions on a BM presentation to business processes, there is an interface that is available that is the common interface to BPML: that is called BPMN Diagrams: Business Process Modeling notation (BPMN: Popkin Software, 2003). BPMN is programmable on BPML, while it has enough structure for us to enable a morphic realization on functionality based on a BM functional scheme (Figure 3.3).

3.2.6 INSTANTIATING MODELS

This level consists of either concrete real-world BMs or conceptualization, representations, and descriptions of real-world BMs. Several authors used the BM perspective to analyze companies, such as Chesbrough and Rosenbloom (2002); Kraemer et al. (2000), General Motors' OnStar project (Barabba et al., 2002), specific online supermarkets (Yousept and Li, 2004) and online media companies (van der Beek et al., 2004). Yet, these authors vary greatly in terms of conceptualization in how they represent these real-world BMs.

A major confusion occurs when the IT and infrastructure management is for the most part resilient to what is built not spontaneous to BMs changes.

The disruption is not easily assimilated and can take year legacy repairs unless the process is more carefully orchestrated, as presented in this paper and the newer research reviewed by our contemporary colleagues.

Considering a view from Nilesen-Lund (2019), for example, we can postulate what role the value parameters play for BMs innovations; here are the stages:

1. Articulate the value proposition, that is, the value created for users by the offering based on the technology;
2. Identify a market segment, that is, the users to whom the technology is useful and for what purpose;
3. Define the structure of the value chain within the firm required to create and distribute the offering;

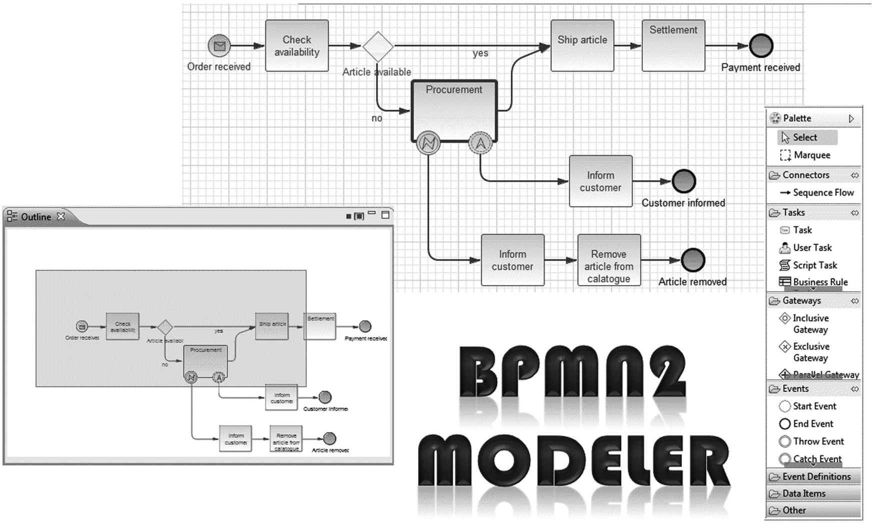

FIGURE 3.3 Eclipse onto SAP BMPN modeler example. (Adapted from Knecht and Biebeler.)

4. Estimate the cost structure and profit potential of producing the offering, given the value proposition and value chain structure chose;
5. Describe the position of the firm within the value network linking suppliers and customers, including identification of potential complementing parties and competitors;
6. Formulate the competitive strategy by which the innovating firm will gain and hold an advantage over rivals.

Following (Nielsen-Lund, 2019) for a glimpse above to a degree, we can stipulate our views on how a BM might be conceived based on the value creation propositions:

- What value creation propositions are we trying to sell to our customers and the users of our products?
- Which links on, for example, on BMPN are we trying to optimize through the value creation of the company?
- How is the product/service of the company unique in comparison to those of major competitors?
- Are there critical links on the different phases of value creation that can be modeled on a business process model to become pragmatics measures?
- Can we identify the activities that, when set in motion, can master the critical links?

- Which resources, systems, and competencies are required to deploy the planned strategy?
- What are the risks that can undermine the success of the chosen BM?
- What can we do to control and minimize these?

3.2.7 BUSINESS MODEL (BM) COMPONENTS AND THE VALUE GOALS

Figure 3.4 is a glimpse of how Section 3.2 views of a BM might be characterized.

George & Bock (2009)	Morris et al. (2005)	Osterwalder et al. (2005)
» Organizational design » The resource-based view of the firm » Narrative and sense-making » The nature of innovation » The nature of opportunity » Transactive structures	» Economical level » Operational level » Strategic level	» Activity/role-related approach » Value/customer-oriented approach

FIGURE 3.4 BM interest views adapted from separate groups.

How value is created and how to measure that with data analytics. Extracting value from your data requires a certain degree of understanding the data, and although descriptive statistics and other forms of profiling are useful tools for this, there is no substitute for exploring your data interactively in a visual manner. The “Explore” phase of the analytics life cycle sets the stage for more in-depth analysis and modeling, enabling you to gain some initial insights from variable distributions and relationships, and providing a realization of the potential payoff that can be expected of predictive modeling. Ultimately, with predictive analytics (realizing what might happen in the future based on the Data on value parameters or variables involved in building models to represent the relationships between input variables and goals. Visual data mining and machine learning (ML) are being deployed to offer these modeling capabilities in different forms that can be consumed by users who have various levels of expertise (e.g., Nourani, 2005).

We in accord with the thought that a BM when deployed on an enterprise management system that enables the strategic choices for a business to become profitable. A BM is concerned with the value proposition of the company but is also supported by some parameters and characteristics, e.g., some of the applied distribution channels, customer relationships, pricing models, and sourcing from strategic links. That is when we must engage a business logic and layers for realizing a BM, i.e., strategy and value proposition of the company leveraged?

3.2.8 COMPARING AND USING YOUR MODELS

Training effective predictive models are somewhat of an art. Beyond applying different data preparation steps, employing feature engineering techniques, and finding the best hyperparameter settings to use, assessment of a model can be carried out using several different metrics. As you interactively build different models, often with different modeling algorithms, a direct comparison can be cumbersome as you look at each model independently. SAS visual analytics provides a model comparison object that enables you to easily compare your models side-by-side in a variety of ways by presenting multiple standard assessment plots, different metrics, and cutoff and percentile selections. Models that have the same variables defined for the roles can be selected to include in the comparison. An overview of value creation from Nielsen-Lund (2019) is as follows:

- New values configurations;
- Firm infrastructure;
- Human resource management;
- Technology development;
- Procurement.

Management drivers: Inbound logistic Operations Outbound Logistics Marketing and sales services. Let us take the view that the BM is the platform that enables the strategic choices to become profitable, what parameters must be valuing. A BM is concerned with the value proposition of the company, but it is not the value proposition alone as it in itself is supported by several parameters and characteristics, e.g., applied distribution channels, customer relationships, pricing models, and strategic partnerships parameters (Figure 3.5).

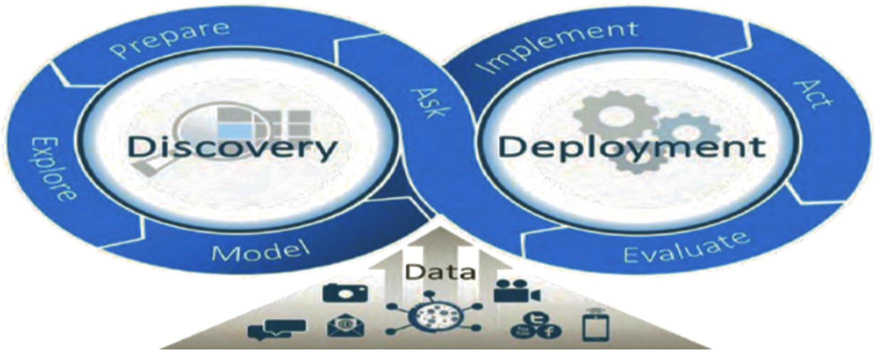

FIGURE 3.5 The analytics ecosystem lifecycle.
Source: SAS AI example 2019.

It is apparent that competition now increasingly stands between competing business concepts. When firms within the same industry operate based on different BMs, competencies, and knowledge resources are key parts of the value creation and success.

3.2.9 WHAT ARE THE INTERDEPENDENCY PARAMETERS?

Examining value creation through BM Innovation one looks for BM Innovations Parameters. Let us have a glimpse review on (Amit-Zott,2012) that identified four major interlinked value drivers of BMs: novelty, lock-in, complementarities, and efficiency:

1. Novelty captures the degree of BM innovation that is embodied by the activity system.
2. Lock-in refers to those BM activities that create switching costs or enhanced incentives for BM participants to stay and transact within the activity system. The authors consider, for example, Nespresso, a division of Nestlé Corporation. It introduced a new, low-cost espresso maker that uses Nespresso-produced coffee capsules. Once a customer buys a Nespresso machine, he or she needs to use it.

   Author's Example: Nespresso coffee capsules—creating a lock-in that enables Nestle to profit from both the sale of the machine and the use of the machine by selling consumables that machine owners must buy from Nespresso.
3. Complementarities refer to the value-enhancing effect of the interdependencies among BM activities.

> Authors consider eBay, with a key requirement for the platform to function properly is a payment system that allows buyers to make credit card payments even when the seller does not have access to credit card services. On the newer fronts, there is the Bazaar on the blockchain that facilitates retail on blockchain payable on cryptosystems (2019).

Example: Launching new products involves a radical redesign of the activity system by branching out into retailing activities.

An innovative BM can either create a new market or allow a company to create and exploit new opportunities in existing markets. For example, a customer-driven, build-to-order BM as opposed to the traditional build-to-stock model of selling products, for example. computers through retail stores.

Changes to BM design might be so seamless so as not to have the potential to disrupt an industry while yielding important benefits. Companies at times change their BMs in incremental ways or follow a BM innovator in their industry to achieve competitive parity.

3.2.10 INERTIA, CAPACITY, AND DEPENDENCY

One thing we should discuss is also why this might not happen. We need to discuss things like the culture of the firm, inertia, path dependency, absorptive capacity are all relevant concept to explain why corporations are not RATIONALE and just use data to quickly change their BM. The stopper is the human factor (Figure 3.6).

Realizing BM interdependencies on enterprise planning entails factoring the business processes to accomplish the BM value creation goals. Factors that affect the determine the business process management and improvement realities are as follows: ERP organizational assessment, change, design, and support, ERP performance measurement and optimization; Training needs analyses and content development; Training delivery and follow-up; Communications planning and execution, Business case design and implementation; Post-implementation audit to track and report progress vs. the business case; Obstacle identification and solution implementation; Process and organizational enhancements designed to fully optimize new enterprise technologies.

FIGURE 3.6 Singularity University adaption.

The corporations need to specify how to conduct business before they implement an ERP system. The best way to do that is by defining how decisions are made in terms of planning. ERP and EM are to be applied to elect supply chain policies, which can in part specify how the business is to operate. Applying resource planning processes appropriate business planning models could be developed. Applying ERP to the planning process, we might develop tactical planning models that plan critical resources up to sales and delivery. Planning and tasking require a definition of their respective policies and processes; and the analyses of supply chain parameters.

Dynamic thinking, that the business world is not static, is a fundamental premise to ERP. Operational thinking is applied when planning for decisions based on how things work and interact. Closed-loop thinking can be applied to control decision trees on ERP when feedback is necessary to carry on new plans or to set new business goals. Experience management (EM) at times can assist in obtaining closed-loop control or be applied to determine the scope of the project to fit within the resources available (including budget) and the time required and to assign responsibility. ERP has to select the operational planning teams that will manage the process. Amongst the tasks are: feasible production schedules, mapping the operational planning process to develop scheduling models for production and plan inventories, developing plans for building a data warehouse, knowledge management (KM), and interfaces to legacy systems. ERP involves implementation teams consisting of business representatives, functional representatives, IT personnel, and system knowledgeable people. The planning and ERP team implement schedules and raise performance problems to appropriate senior management. Gap and risk analysis can be conducted to determine system capability. ERP and EM can be applied to determine flexibility factors to modify implementation plans, as specific functionality domains become critical. There are several papers by Nourani et al. (2005–2020) on the areas.

3.3 DIGITIZATION'S AND VALUE CREATION

Big data, the internet of things, and artificial intelligence (AI) hold such disruptive power that they have inverted the dynamics of technology leadership (Siebel, 2019). Analogs across social and economic history include the discovery of fire, the emergence of agricultural techniques, and, in more recent times, the Gutenberg Printing Press, urban electrification, the automobile, the microprocessor, and the Internet. Each of these innovations collided with a society that had been in a period of relative stasis—followed by massive disruption. Further, landline operators were massively disrupted by cell phones, which in turn were upended by the introduction of the iPhone in 2007—which, in the following decade, has settled into a new stasis, with handheld computing, changing the very nature of interpersonal communication. Currently, drones and autonomous vehicles are the newest disruptions being assimilated with no plans of equilibrium, except for 'nature taking its course.' When it is over, a new equilibrium will emerge. The evidence suggests that we are seeing a mass disruption in the corporate World (Innosight, 2017). Over 50% of Fortune 500 companies have been acquired, merged, or declared bankruptcy, with no end in sight. In their wake, we are seeing a mass "speciation" of innovative corporate entities with largely new DNA, such as Amazon, Box, Facebook, Uber, and WeWork. Mass-extinction events do not just happen for no reason. In the current ongoing disruption, the reason is here labeled 'digital transformation.'

New digital technologies are transforming every industry and the digitization process has triggered a broader 'digital transformation' phenomenon across most industries and firms (Loebbecke and Picot, 2015; Richter et al., 2018; Ghosh et al., 2017; Butschan et al., 2018). There is no commonly accepted definition of the term digital transformation (Schallmo et al., 2017). In this paper, the concept is defined according to Fitzgerald et al. (2013): the firm uses new digital technologies to enable major business improvements. The challenge for firms is not to add a digital touch to their current practices and products, which could be viewed as product and process innovations

(Amit and Zott, 2012), but to fully exploit digital technologies transformative potential by creating BM innovations (Venkatraman, 1994; Fitzgerald et al., 2013; Nielsen and Lund, 2014; Teece, 2018).

A BM describes how a firm creates and delivers value to customers and how a firm will capture a share of that value. A success of a business depends as much on BM design and implementation as it does on the selection of technologies and the operation of tangible and intangible assets and equipment (Teece, 2018). Chesbrough and Rosenbloom (2002) go even further and state that the BM is a focusing device that mediates between technology management and economic value creation. In this context is of importance to ask the question if digital technology and the digitization of many business processes could support in identifying areas for value creation for the firm.

3.3.1 AREAS FOR VALUE CREATION

The literature confirms that digitization is having a positive impact on the economy (Bleicher and Stanley, 2018). However, validated frameworks for analyzing digitization's effects on BM and business process innovations are limited (Schallmo et al., 2017). One stream of research that has presented a framework in the area of strategic management and information technology (IT) (Steiber and Alänge, 2020). The MIT-developed framework presented in Venkatraman (1994) could support in the analysis of value creation as an effect of different degrees of digital transformation of the firm (Figure 3.7).

Below each of the five levels will be briefly described:

- **Level 1: Localized Exploitation:** This is according to the author the very first level in a business transformation, enabled by IT. In this phase, the company enables IT by deploy it in isolated systems such as, e.g., inventory control system. The result is isolated learning of benefits and limitations from such initiatives.

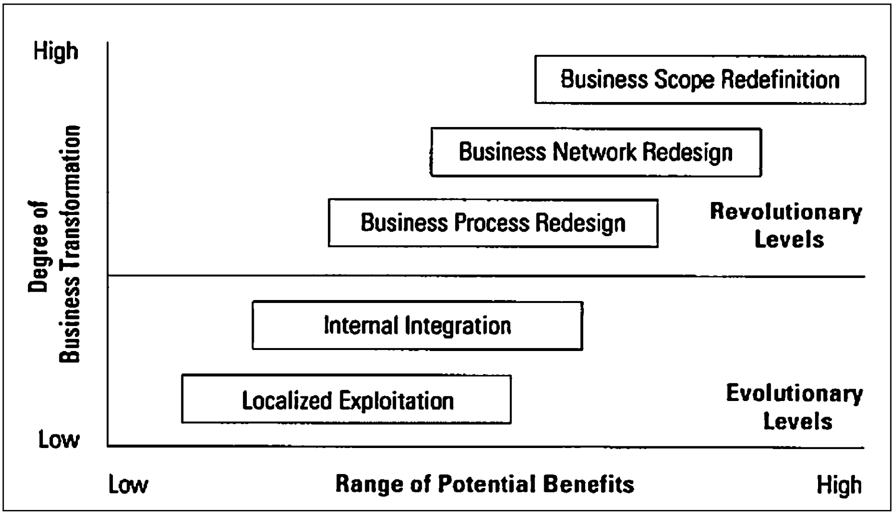

FIGURE 3.7 Five levels of IT-enabled business transformation.

Source: Adapted from the MIT Sloan reviews (1994).

- **Level 2: Internal Integration:** The second level is reflecting a more systematic attempt to leverage IT throughout an entire business process. According to the author, this level integrates technical interconnectivity and business process interdependence. Both types of changes are needed on this level.

  On both levels mentioned above, one value created is the lowering of the cost of interaction. The more exchanges, the higher the potential benefits. On the second level, a lower transaction cost could also be the case as a transaction between, e.g., departments now could be automatic and seamless without any human interaction involved. One value created is also a higher level of information symmetry, as more information will be accessible for all participants (Reddy and Reinartz, 2020). Further, big data analytics and therefore an effective decision making is hard to leverage when departments live and act in silos (Jha et al., 2016). Analytics using big data for business intelligence within an organization is required to support critical operational processes of an enterprise. Organizations generate around one-third of the data they use internally and are responsible for around 85% of the remaining two-thirds of data, generated via consumers interacting with their services, and every data point is potentially valuable (Jha et al., 2016).

One example of the economic value of digitizing single processes is coming from Markovitch and Willmott (2014). The case is a bank that digitized its mortgage-application and decision process, cutting the cost per new mortgage by 70% and slashing time to preliminary approval from several days to just one minute.

- **Level 3: Business Process Redesign (Reengineering):** On the third level, IT is used as a lever for designing the new organization and business processes. This level is based on the rationale that the benefits of IT are not fully realized if superimposed on the current business processes. Business process reengineering (BPR) involves the radical redesign of core business processes to achieve dramatic improvements in productivity, cycle times, and quality (Jha et al., 2016). By later digitizing the new process, the three areas of economic value could improve even further. Business processes need to be reengineered to fit unstructured and semi-structured data (Jha et al., 2016). The organizations need to determine the critical processes (e.g., product development, marketing, selling, customer care) that need to be radically changed to realize quick wins in the areas of business performance improvement and/or cost reduction undertakings. Some examples on economic values from digitizing a reengineered business process are: improved customer satisfaction (improved user experience); reduced business and IT costs; increased profitability; increased responsiveness; and improved quality of execution and decision making (improved internal processes) (Jha et al., 2016).
- **Level 4: Business Network Redesign (BNR):** On the fourth level of transformation, IT enables interconnections and integrations with external partners such as suppliers, customers, and other intermediaries.

Literature on platform markets in modern interconnected industries indicates that this fourth level of business transformation leads to business value in the form of lowering the transaction costs (Cozzolino and Giarratana, 2014). The fourth level could also lead to a transformation from pure value creation to value co-creation between the firm and its customers through digitization (Rantala and Karjaluoto, 2016). The authors studied value co-creation in health care and found that a new mode of interaction in value-co-creation in which both parties are independent in their own spheres, but the service (via digital platform) is available to both and has a timewise continuum that differs from traditional episode-based meetings between the parties. This could in turn lead to further value creation for both the firm and for their customers. Other values created on this level could be an increased transparency, less information asymmetry (which could lead to lower prices), and new services or even products to the customer (Reddy and Reinartz, 2017). According to Bleicher and Stanley (2018), the Internet has enabled organizations to improve customer and supplier interactions and processes and has allowed optimize communication and information flow, reduce inventory, better understanding of preferences and an increased turnover, resulting in financial benefits. One example on a BNR towards suppliers, is the adoption of digital supply chain systems to transact and coordinate with the firm's partners. The adoption of digital supply chain systems does, however, not only create value for both partners, but could also be a risk for the firm. According to Xue et al. (2013), firms face both technological risk and transactional risk when they adopt digital supply chain systems to support their interfirm business processes. Technological risk mainly refers to the uncertainties and potential negative outcomes caused by technological changes and challenges in building, implementing, and using digital supply chain systems together with partners. Transactional risk mainly refers to the uncertainties and potential negative outcomes caused by the strategic behaviors of supply chain partners in misusing digital linkages and exploiting the interfirm relationships. These risks, however, could be, according to the authors, mitigated by using system modularity[1].

- **Level 5: Business Scope Redefinition (Business Model (BM) Redefinition):** The final level is reached if the firm utilizes IT to influence its business scope and the general logic of their business relationships. According to the author, this last level is dependent on a redesign of the firm's business networks (level 4), that is that the company moves from transaction processing to knowledge networks. Technology in this phase redefines the rules of the game (Venkatraman, 1994, p. 84). The business value created on this level could be tremendous. One example is new BMs such as Airbnb, which has disrupted the whole hospitality industry. According to this BM, there is no need for large investments in hotels and there are tremendously fewer personnel costs, etc. According to Bleicher and Stanley (2018), the transformation of industries in the digital age forces organizations to rethink their BMs.

[1] Modular systems usually have loosely coupled components and subsystems that interact through well-defined standardized interfaces (Xue et al., 2013).

3.3.2 MEASUREMENTS OF VALUE CREATION

While business press suggests that firms such as Cisco Systems, Dell Computer, and general electric (GE) have achieved performance gains by leveraging the Internet and digital technologies, there is no systematic evidence in the IT productivity or business value literature regarding the payoffs from those technological initiatives (Barua et al., 2004). While there is very limited literature on the economic payoffs from Internet-based business initiatives, there is a richer body of knowledge in the domain of IT productivity and business value (Barua et al., 2004). Reasons are among others; measurement problems as well as the availability of reliable data.

Barua et al. (2004) present an exploratory model of electronic business value. The model is including three levels: (a) E-business drivers; (b) operational excellence measures, and finally; (3) financial measures. The e-business drivers are IT applications, processes as well as E-business readiness among suppliers and customers. Operational excellence measures are, for example; percentage online business, customer acquisition, procurement or customer service, as well as order delivery time reduction. Finally, financial measures are, according to the authors' percentage increase in revenue per employee, gross profit margin, return on assets, and return on invested capital related to electronic business initiatives. The authors tested the model on 1000 firms in the manufacturing, retail, distribution, and wholesale sectors and found that the construct is highly reliable. The results obtained suggest that the effects of both customer and supplier excellence on financial measures are significantly positive. The result also validated the linkages between operational (customer and supplier) excellence and driver constructs related to IT applications and business partners' readiness, not processes. One reason for this is, according to the authors, that in most firm's coordination and learning are still needed within the value chain for simultaneous adoption of Internet-based business practices by all partners, that is processes will play a more important role in the future when firms and inter-organizational value chains are digitized to a higher degree.

3.3.3 IMPLICATIONS

Based on the above, the digitization of business has both direct and indirect positive effects on the firm's financial performance. It was also clear that a higher level of business transformation of a firm leads to a higher impact on the firm's financial performance. This was also found in an exploratory study by Barua et al. (2004) that found that IT investments alone cannot lead to higher business value (also supported by Steiber and Alänge (2020), as well as IT investments in isolation (within a single department or a single firm) is limiting the financial effects from digitization. Finally, measuring the effects on financial performance has historically been hard as it has not been reliable. The exploratory study by Barua et al. (2004) found, however, that their construct (conceptual model) is reliable and that operational excellence due to digitization does lead to positive effects on the financial performance of the firm. However, more research on measuring digitization's effect, as well as how digitization can support in improving measuring digital technologies' effects on financial performance, is needed.

3.4 AI DIGITIZATION MANAGEMENT STRATEGIES

Reestablishing an equilibrium is nontrivial, requiring an ecosystem framework for thinking about disruption in today's economy.

Drones, Uber, and autonomous vehicles are the newest disruptions being assimilated with no equilibrating ecosystem plans, except for nature taking its course. When it is over, and it is not over till it is over, a new equilibrium will emerge. Landline operators were massively disrupted by cell phones, which in turn were upended by the introduction of the iPhone in 2007—which, in the following decade, has settled into a new stasis, with handheld computing changing the very nature of interpersonal communication. The evidence suggests that we are seeing a mass disruption in the corporate world. Over 50% of Fortune 500 companies have been acquired, merged, or declared bankruptcy, with no end in sight. In their wake, we are seeing a mass "speciation" of innovative corporate entities with largely new DNA, such as Amazon, Box, Facebook, Uber, and WeWork. Mass-extinction events do not just happen for no reason. In the current disruption event is digital transformation. But that is a broad term that can include putting massive servers on a net or block chaining all banking transactions on digital certificates.

A BMW example: Frankenberger-Weiblen-Gassmann (2014) when not changing BMs while merging with a second enterprise to create values for the same BM. Realizing that its existing co-development relationships with automotive suppliers did not lead to attractive results, BMW's revolutionary in-car control concept iDrive was developed in collaboration with Immersion, a high-tech company that previously had no experience with the automotive industry. The collaboration was limited to the single purpose of integrating Immersion's haptic feedback technology into BMW's onboard control system. Immersion accounted for the first feasibility studies, then development responsibility moved on to BMW's R&D department and, later, to an established automotive supplier, while Immersion provided technical advice. Thus, the BM of either company did not have to change significantly and sustainably, while BMW was still able to differentiate itself from other automakers through its innovative product models: an exploratory study of incumbent firms (Karolin, Tobias, and Oliver, 2014). Some specifics on digitizations directions at Germany might be viewed on Ralf, Tim, and Annette (2017).

3.4.1 BIG DATA AND DIGITIZATION

Over the past five years, the digital banking revolution before and since towards blockchain ledgers impact on the relationship between customers and the institutions that handle their money. The rise of online banking along with its accompanying wave of digital-only challenger banks-mobile payments and increasingly personalized money management tools have given birth to a FinTech industry expected to reach an estimated value of more than $305 bn by 2023. The driving force behind this sweeping digital transformation is the exponential growth of big data which, when twinned with cutting-edge AI and ML analytics, has created actionable insights that are leading financial institutions down a road towards a customer-centric, hyper-personalized financial future.

Novel predictive modeling analytics techniques with decision trees on competitive models with big data heuristics are presented in brief. Spanning trees are applied to focus on plan goal models that can be processed with splitting agent trees and vector spanning models. Sparse matrices enable efficient computability on big data heuristics. Predictive analytics on "big data" are presented with new admissibility criteria (e.g., Nourani et al., 2018). Tree computing grammar algebras semantic graphs are a basis for realizing tree goal planning examples. The areas explored in this paper range from plan goal decision tree satisfiability with competitive BMs to predictive analytics models that accomplish goals on a 3-tier business systems design models. Attention spanning trees are applied to focus on plan goal models that can be processed on a vector state machine coupled with a database pre-processor data mining interfaces (Nouran-Lauth-Pedersen, 2015). Modeling, objectives, and planning issues are examined to present precise decision strategies to satisfy such goals.

Heuristics on predictive analytics are examined with brief applications to decision trees. Business intelligence and analytics (BI&A) and the related field of big data analytics have become increasingly important in both the academic and business communities over the past two decades. Section outlines are as follows: Section 3.2 presents the basics on competitive goals and models Agent and/or trees are applied as primitives on decision trees to be satisfied by competitive models. Planning with predictive models and goals are presented with stock forecasting examples from the first author's newer decade's publications. Section 3.3 briefs on goals, plans, and realizations with databases and knowledge bases. There a function key interface to the database is presented with applications to model discovery and data mining. Competitive model goal satisfiability with model diagrams is glimpsed. Section 3.4 presents the applications to practical decision systems design with splitting agent decision trees. The paper concludes with heuristics for competitive models and goals comparing with Russell and Norvig (2002) from the first author's newer economics game decision tree bases. Digitization analytics is for machines and ML forward to process (Figure 3.8).

The value of big data is only multiplied by good data governance. Big data has a big value, it also takes organizations big effort to manage well and an effective governance discipline can fulfill its purpose.

3.4.2 THE BIG DATA EXPONENTIALS: CONTENT, APPS

Consumers have been pledging their love for data visualizations for a while now, and data mining with multimedia discovery is the area being explored. Big data is a popular term used to describe the exponential growth and availability of data, both structured and unstructured. More accurate analyses may lead to more confident decision making. And better decisions can mean greater operational efficiencies, cost reductions, and reduced risk. Our novel techniques apply nondeterministic data model diagram filters to span big data spaces.

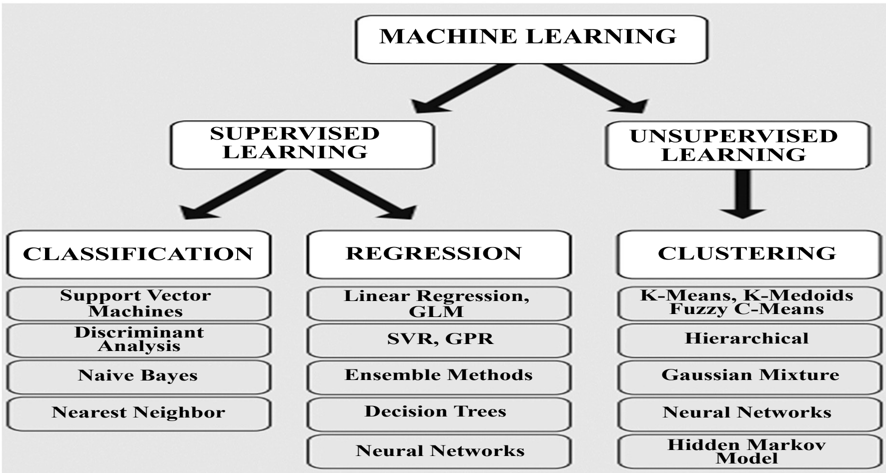

FIGURE 3.8 Machine learning overview.

Source: Adapted from Data Science Central. With permission from Vincent Granville.

3.5 ALTERING VALUE CREATION ON BUSINESS PROCESS MODELS

Here we depict an illustration with a SAS example AI can be deployed to accomplish altering value creation with business process models (Figure 3.9).

Towards data-driven organizations, supporting organizational decisions with data analytics, one must prioritize that not all decisions are equally important. Decisions must be prioritized based on the relative value created:

- When building a data-driven organization, one must first choose the decision rules. Next, an agenda table must be provided comprising.
- Which decisions apply to what data or content aggregates?
- How to categorize decisions?
- How to prioritize decisions?
- Capital Investment decisions?
- Strategic Direction decisions?

The CE view (Lüdeke-Freund and Gold, 2018; Bocken et al., 2016) is essentially a macroeconomic ecosystem that supply chain is a driver for value creation. Creating value with closed-loop supply chains sustainable to circular BMs whether the reverse cycles defined above can be translated into viable business (i.e., value creation for the company and its customers), and even into a sustainable business that creates ecological and social value, is a question of BM designs that successfully build on CE principles under given

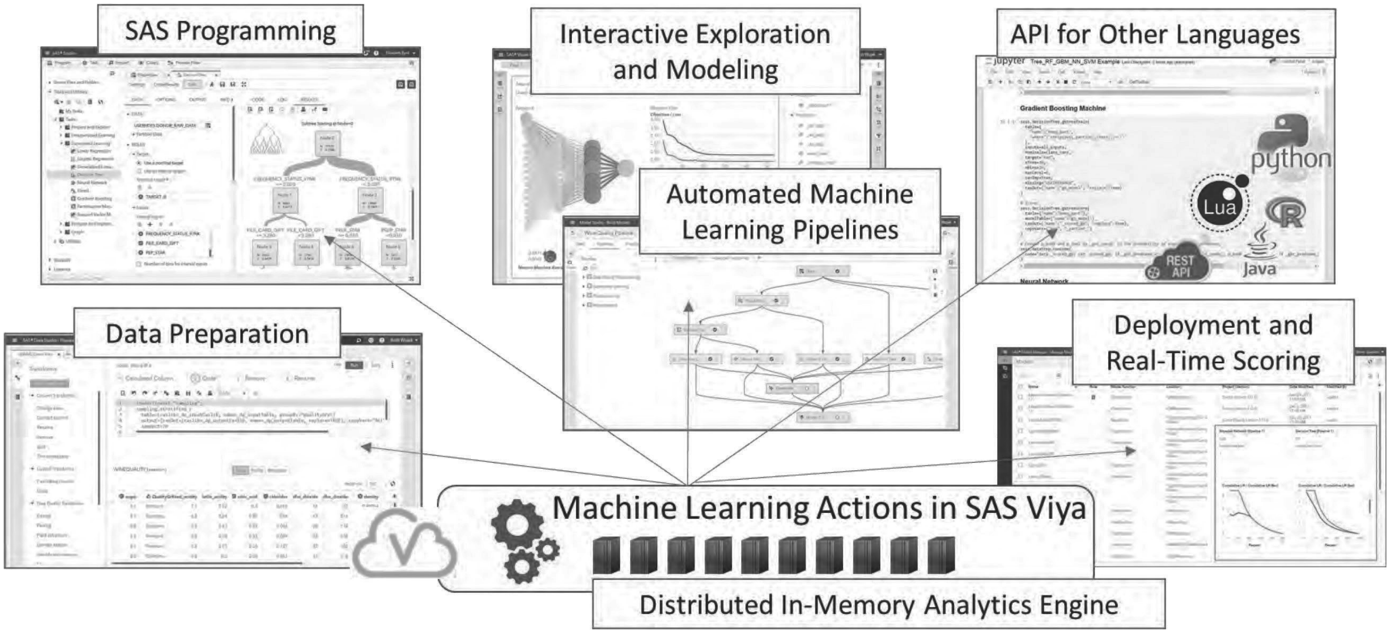

FIGURE 3.9 An example of how there might be IT-enabled business model transformations.

Source: Reprinted from Gupta, 2018. © 2018, SAS Institute Inc.

market conditions (cf., Wells and Seitz, 2005; Nourani, 2017), the latter being on the open system ecosystems economics agilities. Typically, BMs are representations of how businesses create economic value for a company through the creation of value for its customers. There is some consensus that these representations aid in describing, analyzing, communicating, managing, and designing the value creation systems of companies, business units, or other kinds of an organization (Massa et al., 2017; Zott et al., 2011).

3.5.1 OPTIMIZING VALUE CREATION

Value creation can be subdivided into:

1. Value propositions (i.e., the benefits offered to customers based on products, services, or product-service systems);
2. How value propositions are delivered to customers by engaging actors and value delivery processes;
3. How value is created (i.e., the actors and activities involved in value-creating processes, including production);
4. How focal companies capture part of the created value).

Value capture is based on the systematized processes to accomplish the above to maintain the ability to develop and deliver value propositions.

Our systems view business management applies a known categorical process called a pullback on a business systems model. Considering the BM examples from the preceding section (Figure 3.9), the BM structures can be pulled back with a BPMN model diagram that is mapped to the BPML language processor for EM or enterprise planning, for example. For a startup example, the BM overview links for value creation pull-backs are as follows Nourani et al. (2010–2017). Considering the Mission is the BM, the macro pull-back is on the arrow links with a forward delivery push based on the market forecast. Predictive analytics, and supply chain. The pull-push process is a known categorical mathematical system process for realizing systems. Here we are instantiating that on a startup example business system (Figure 3.10).

Competitive BMs and Loop Control. New optimality principles are put forth based on competitive model agent business planning. A Generalized MinMax local optimum dynamic programming algorithm is presented and applied to BM computing where predictive techniques can determine local optima. A competitive BM technique, based on the author's planning techniques is applied. Systemic decisions are based on common organizational goals, and as such, business planning and resource assignments should strive to satisfy higher organizational goals. It is critical to understand how different decisions affect and influence one another. A preliminary optimal game modeling technique was presented in brief. Example application areas to e-commerce with management simulation models are examined with a Stanford flight simulator model (e.g., Nourani, 2010–2018).

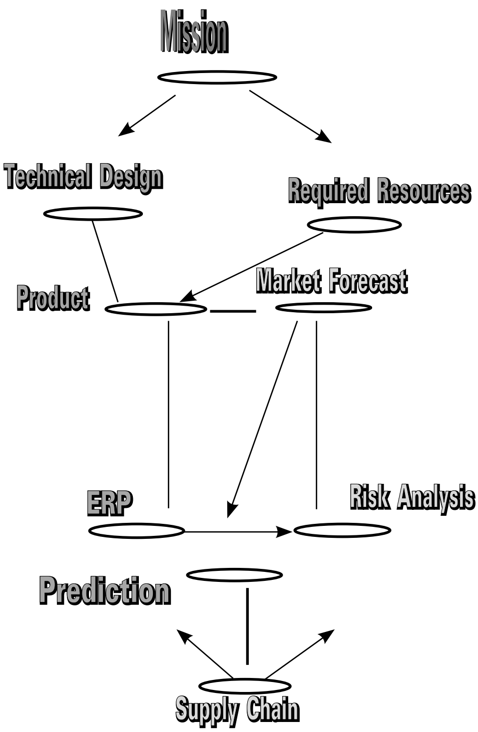

FIGURE 3.10 Startup example pull-push mission to market optimizer.
Source: Nourani AA Press (2018).

3.5.2 HOW TO REFLECT VARIANCES AND BUSINESS MODEL (BM) TO EM

Starting with a trivial BM; a pullback stage is something like:

- What kind of products or services?
- How is value created for the products or services?
- What countries are buyers?

The value creation net is developed based on the above parameters. BM innovation can occur in several ways; here are some specifics:

- By adding novel activities. Let us refer to this form of BM innovation as a new activity system that is "content" driven.
  - o A pull-back for this entails adding additional processes on a BPML for the new activities with the newer content and action implications.
- By linking activities in novel ways; this type of BM innovation has a new activity system "structure."
  - o A pull-back for this type of innovation has to accommodate infrastructure changes as well as reorganizing the processes on a BMPL reflecting the pull-back.
- By changing one or more parties that perform any of the activities; we refer to this form of BM innovation as a new activity system "governance."
  - o Content, structure, and governance are the three design elements that characterize a company's BM.
  - o A pull-back for this kind has to essentially first compose a BM as having both content and novel activities that have new value creation links that are controlled by additional directives based on the governance structure on a BMPL. Figure 3.11 summarizes the process.

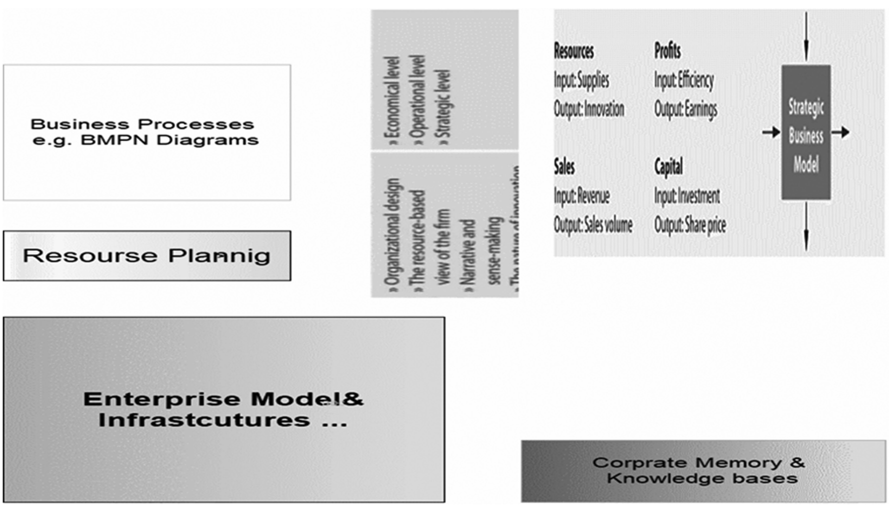

FIGURE 3.11 Business model systematic overview.

3.6 COMPETITIVE MODEL RANKS ON BUSINESS PLANNING

This section examines predictive models as a basis to carry structures modeling towards a competitive culmination problem where models "compete" based on goals and model rank tress. A model rank is higher when on decision trees with a higher degree, satisfying goals, hence realizing specific goals, where the plan goals are satisfied. Characterizing competitive model degrees on random sets (Nourani, 2018).

A model is a competing model iff at each stage the model is compatible with the goal tree satisfiability criteria. Compatibility is defined on Random Sets where the correspondence between compatibility on random sets and game tree degrees is applied to present random model diagrams. Random diagram game degrees are applied and model ranks based on satisfiability computability to optimal ranks are examined.

3.6.1 COMPETITIVE MODELS VARIED ON BUSINESS GOALS

The data modeling impact on the pullback from a new BM.

1. **Modeling:** Exercising feature engineering techniques, applying algorithms to identify segments and build representations for classifying new observations and making predictions, and assessing and tuning the generated models.
2. **Model Deployment:** Selecting champion models and promoting them for use in a production environment to aid in making effective business decisions.
3. **Model Management:** Maintaining a version-controlled repository of models, incorporating them into decision-making processes, monitoring their performance over time, and updating them as necessary to ensure that they are adequately and accurately addressing your business problem.

Planning is based on goal satisfaction at models. Plan goal selections and objectives are facilitated with competitive agent learning. Predictive modeling is an AI technique defined since the first author's model-theoretic planning project. It is a cumulative nonmonotonic approximation attained with completing model diagrams on what might be true in a model or knowledge base. A basis for forecasting is put forth at preliminary stages in the first author's publications (e.g., Nourani, 1997, 2013) can be carried out applying facts and the defined relationships amongst objects. Referring to the example in the preceding sections from Nourani (2018a). A scheme might be Intelligent Forecasting {IS-A Stock Forecasting Technique} Portfolios Stock, bonds, corporate assets Member Management Science Techniques. The above scheme with the basic logical rules, can form a basic theory T to reason about a stock forecasting technique. To do predictive analysis we add hypotheses, for example, the singular propositional pi based on the following:

p1. Asset (Stocks); p2. Stock (x) => Asset (x); p3. S&P100
(x) => Stock (x)

The above scheme or with the basic logical rules, can form a basic theory T to reason about a stock forecasting technique. To do predictive analysis, we add hypotheses, for example, on the propositional literals based on the following: p1. Asset (Stocks); p2. Stock (x) => Asset (x); p3. S&P100 (x) => Stock (x)

A predictive diagram for T is constructed starting with p1 = True, p2(f) = true for f ranging over stock symbols, p3 is true

for all x = f, where f is a stock symbol in the S&P100.

3.6.2 GOALS, PLANS, AND BUSINESS MODELS (BM)

A practical management strategy is carried out by modeling with information, rules, goals, and analytics data. Data and knowledge bases, value nets, where masses of data and their relationships representations are stored respectively. A novel basis to decision-theoretic planning with competitive models was presented in Nourani (2005) and Nourani-Schulte (2013) with classical and non-classical planning techniques from AI, games, and decision trees, providing an agent expressive planning model. Planning with predictive model diagrams represented with keyed to knowledge bases is presented. Model diagrams allow us to digitally characterize incomplete knowledge to key into the incomplete knowledge bases.

Reflecting on the above sections a competitive model ranking process might be characterize by the following:

1. Novelty captures the degree of BM innovation that is embodied by the activity system: what model realizes the value parameters.
2. Lock-in refers to those BM activities that create switching costs or enhanced incentives for BM participants to stay and transact

within the activity system: that is a choice on a decision tree that select a forward move that can no longer be realized by alternative models.

3. Complementarities refer to the value-enhancing effect of the interdependencies among BM activities.

A good summary might be the St-Gallen's BMI Lab BM navigator: The magic tringle is summarized by Who: Every BM serves a certain customer group (Chesbrough and Rosenbloom, 2002; Hamel, 2000). Thus, it should answer the question ′Who is the customer?′ identify the definition of the target customer as one central dimension in designing a new BM. What: The second dimension describes what is offered to the target customer, or, put differently, what the customer values: simply, the value proposition (Teece, 2010; Osterwalder, 2004). How: To build and distribute the value proposition. Value: The fourth dimension explains why the BM is financially viable; thus it relates to the revenue model. In essence, it unifies, for example, the cost structure and the applied revenue mechanisms, i.e., how to make money in the business.

3.7 CONCLUDING COMMENTS

What could be possible? That is the opportunity if predictive analytics would have been used more frequently for innovating the firm's BM. On enterprise modeling pragmatics areas, we have a decade of work done on model refactoring on Section 3.3 areas for BM reengineering and considering how BPMN-BPML can be applied to accomplish the BM innovations that might be applicable when it comes to building enterprise systems down the road a few years. Our process allows accommodating BM innovation while optimizing EM based on existing resources. The process affords business with systematic business process management sequences to remain competitive and profitable while retaining near full EM, however, functionally restructured. Digitization of a business has both direct and indirect positive effects on the firm's financial performance. On the IT areas, investments in isolation (within a single department or within a single firm) is limiting the financial effects from digitization. However, more research on measuring digitization's effect, as well as how digitization can support in improving measuring digital technologies' effects.

KEYWORDS

- **AI digitization**
- **business process modeling language**
- **competitive models**
- **economics ecosystems**
- **enterprise modeling**
- **model compatibility**
- **predictive modeling**
- **structural reflective models′ transformations**
- **typologies**
- **value creation links**
- **value optimization EM**

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CHAPTER 4

TOWARD A QUANTUM THEORY OF COGNITIVE AFFECT FROM POE TO ROBOTIC HELPERS: NEWTON, AROUSAL, AND COVALENT BONDING

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ABSTRACT

This is the first article to discuss the neuroscience of facial recognition psychopathy in the context of artificial intelligence (AI) as an efficacious way to help men, women, and children whose suffering from this affliction is well documented. The investigation begins with my advocacy of robotic helpers as a palliative means to alleviate the cognitive plight and behavioral problems of individuals whose untreated facial recognition psychopathy also represents a risk to the safety and security of their social environment. Salient examples of victims of facial recognition psychopathy include patients diagnosed with Alzheimer's syndrome, incarcerated offenders with a high recidivism rate, and fugitive felons who successfully elude detection as killers because they appear to be model citizens. My textual analysis of two hitherto undiagnosed cases of facial recognition psychopathy in two psychological tales by legendary American author Edgar Allan Poe illuminates' ways in which this disease affects modern society. As a literary comparatist, I examine the thoughts, words, and actions of the husband in Poe's "Ligeia," demonstrating that he bears a resemblance to serial killers of unsuspecting women. I then analyze the narrative discourse of the gambler in Poe's "William Wilson" to show that facial recognition psychopathy causes

the befuddled narrator to project his self-hatred and suppressed conscience on men in his social circle. Contributing to research on facial recognition psychopathy through the textually oriented study of literary representations of reality facilitates the in-depth understanding that may result in helping specialists in the new field of robotics to design devices to enable otherwise handicapped victims of facial recognition psychopathy to participate in their social milieu if they are diagnosed early enough.

4.1 INTRODUCTION

Cyrus F. Nourani devotes Chapters 5 and 8 in *Ecosystems and Technology*: *Idea Generation and Content Model Processing* (Innovation Management and Computing) to the healthcare domain, providing “an overview” of “various methods” for identifying “unmet needs” and “building a successful innovative program for affordable medical technology.” Case studies “highlight the thought process” in developing successful programs at Stanford Biodesign, Johns Hopkins’s innovation platform, CAMtech’s innovation platform, InnAccel’s acceleration program, and government-run incubation programs (xvii). Although the idea that artificial intelligence (AI) can palliate or heal illnesses is new, considerable research suggests a widespread interest in facial recognition psychopathy, including outstanding articles such as T. H. Pahn, and P. Philippot, “Decoding of facial expression of emotion in criminal psychopaths” in the *Journal of Personality Disorders* (Pahn and Philippot, 2010). The present study responds to a growing healthcare demand for palliative medical devices designed for patients diagnosed for, and clients starting to suffer from, facial recognition psychopathy. The methodology of comparative literary analysis facilitates a discussion that stresses hitherto undetected, hence virtually untreated, signs, and symptoms of facial recognition psychopathy. My close reading of “William Wilson” and “Ligeia,” by Edgar Allan Poe (1809–1849), suggests the importance of understanding and helping patients along a wide spectrum of backgrounds who suffer deficits in facial recognition, while indicating just how their illness could adversely impact their families, friends, co-workers, and community.

Growing numbers of persons have difficulty with facial recognition, including such diverse categories as persons in some stage of Alzheimer’s syndrome and, at the other end of the spectrum, male serial killers. This chapter hypothesizes that something like an Android application, which resembles “Alexa” and “Cortana” would be helpful. It is a well-known fact that men and women who contract Alzheimer’s survive for years after diagnosis. Recidivism among prisoners is increasing even with intramural education and therapeutic intervention programs. A robotic or hand-held device that prompts severely absent-minded and clinically diagnosed individuals suffering from negative ability to recognize faces would experience an improvement in their lives if they could be trained to use a computerized device that prompts them and lifts them out of their forgetfulness. This chapter advocates product development in the medical technology community of an innovative computerized device specifically designed to help individuals who suffer from facial recognition psychopathy in one form or another.

4.2 TWO TYPES OF FACIAL RECOGNITION PSYCHOPATHY

Recent scientific research shows that deviant right hemisphere face processing is associated with two types of psychopathy: (a) fearless dominance; and (b) impulsive antisociality. Fearless dominance is associated with adaptive demographic and personality features, including "high social potency, narcissistic personality features, and interpersonal features of psychopathy, such as low-stress reaction, low harm avoidance, and reduced fears and anxiety" (Benning et al., 2005). Impulsive antisociality is correlated with maladaptive personality traits and life outcomes manifesting in impulsive and antisocial symptoms of psychopathy. Impulsive antisociality is selectively associated with "traits of alienation and aggression, anger, antisocial behavior and substance abuse, low socialization. along with impulsivity, low control, and low sociability" (Benning et al., 2005). Recent investigations are somewhat limited in being restricted, for example, to studying reactions of subjects to viewing pictorial paradigms, which may raise questions as to the reliability of the results (Wilson).

4.3 FACIAL RECOGNITION PSYCHOPATHY IN LITERATURE: COGNITIVE AND AFFECTIVE NEUROSCIENCE

My critical analysis of two texts by Edgar Allan Poe, a revered American master of psychologically symbolic storytelling, provides an enriched context of virtual reality that tends to corroborate experimental laboratory findings. Poe gives us two surprisingly realistic stories: "Ligeia" is an ultra-romantic love story and "William Wilson" is a classic doppelgänger tale of mystery and imagination.

My textual analysis of "Ligeia" (1838) demonstrates pitfalls encountered by two vividly portrayed fictional female protagonists, who may be interpreted as archetypal symbols of woman as an (unrecognized) conscience figure or animus (Jung 9), with a man who presents himself as a suitable marriage partner. Contrary to appearances, the man, whose cognition appears superior, has a virtually undetectable, nonetheless psychopathological, disability in being unable to recognize faces. Unaware of his facial recognition psychopathy, the women, who are pleased to be pursued by an ardent and devoted suitor, unwittingly wed him. "Ligeia" is a first-person narrative told by a man who successfully woos and wins the affection of two unsuspecting women. The storyteller is a two-time widower who recounts memories he has of his first marriage to a beautiful brunette scholar, whom he profoundly respects, and then of his second marriage to a lovely blonde with whom he falls passionately in love. He concludes his narrative with a sensational twist, claiming that at the moment of her death, his second wife was transformed into his first wife. This associative pattern indicates glimpses of moral consciousness, but self-alienated, deeply repressed, and unacknowledged. He is cognitively impaired by fearless dominance. His moodiness counterpoints Ligeia's displays of emotion, which he badly misinterprets. Initially, his impulsive antisociality manifests indirectly and imperceptibly, but then culminates in acute episodes of violence when his facial recognition psychopathy grows so intense as to find expression in homicidal mania that satisfies his overwhelming desire for social position and greed for gold (cf. Whalen).

An inability to recognize faces impairs the male protagonist in Poe's "William Wilson" (1839), a doppelgänger tale of conscience. Wilson is a hard drinker and gambler who displays fearless dominance as a self-indulgent gentleman of leisure who dissipates his fortune. Wilson evinces the dual personality of a strong-willed man of action whose bravado is undermined by hallucinations. To all appearances, he is fearless in public places where he makes a show of savoring his winnings. But he is afflicted by hallucinations that suggest the personality of a man who suffers from paranoid schizophrenia. Symptoms of his face recognition psychopathy propel the story's plot, which follows a trail of evasion as he attempts to escape from the watchful eye of his nemesis, a man who resembles him. But, in reality, the mirror image he sees with his eyes is, in actuality, a psychological self-projection, one that symbolizes his conscience. His suppressed feelings of guilt over his dissolute lifestyle distort his eyesight in a morally significant way. In his devil may care abandonment of integrity, he throws caution to the wind, and yet, he has a latent awareness of his social image as a profligate roué. While he flaunts his willful disregard of the disapproval of his social milieu and risks being an outcast, a pariah, he nonetheless retains a modicum of the moral sense. For these reasons, he speaks as one who stands apart, but is surrounded by detractors. Carl G. Jung (1875–1961) observes hypothetically that "a certain individual shows no inclination whatever to recognize his projections. it is not the conscious subject but the unconscious that does the projecting. The effect of projection is to *isolate the subject* from his environment, since instead of a real relation to it, there is now only an illusory one. Projections change the world into the replica of one's unknown face" (Jung 8). William Wilson fails to recognize everyone he sees, because his suppressed feelings of guilt stifle his facial recognition ability, substituting instead imagery based on his unacknowledged hostility toward himself for engaging in questionable social behavior.

4.4 ROBOTIC PALLIATIVE HELPER FOR TREATMENT OF ALZHEIMER'S SYNDROME

Both of these imaginative literary pieces delve deeply into relationships of facial recognition to emotional processing, neurocognition, and symptoms of perceptual malfunctioning that are associated with medical conditions that are difficult to detect and diagnose. This chapter breaks new ground in its exploration of the association between facial recognition and affective emotional processing in conjunction with technology using, not lab experiments, but vivid examples drawn from Poe's *Tales of Mystery and Imagination*. Because of the increasing numbers of persons who have difficulty with facial recognition, including male serial killers and persons in some stage of Alzheimer's syndrome, an Android application that resembles "Alexa" and "Cortana" is needed.

It is a well-known fact that men and women who contract Alzheimer's survive for years after diagnosis because their caregiver helps them to remember "table," "apple" and their dear friends, neighbors, and relatives. Dimitri Ketchakmadze, in *Alzheimer's Disease: Symptoms, Stages, Hypotheses, Factors, Prevention, and Treatment* (2019), graphically shows the difference between neurons in the hippocampus of the normal brain and the cortical shrinkage, neurofibrillary tangles, severely enlarged ventricles, and beta-amyloid plaques that prevent vital neuronal interaction (brain cell communication) in the Alzheimer's brain. The slow encroachment of "mitochondrial dysfunction" contributes to the process of "cognitive decline and neurodegeneration" in the Alzheimer's brain." Contrary to popular opinion, Alzheimer's differs from normal age-related memory impairment, which is caused by Tau-protein dysfunction, and also from cognitive impairment associated with dementia, where "Tau-protein dysfunction" impacts the cortex by cell-to-cell transmission, causing neuronal dysfunction and degeneration that leads to total system failure. The normal brain is robust, in striking contrast to the Alzheimer's brain, where the neurons gradually shrink. As though injected with poison, the brain loses protein, which is replaced by nitrogen, hydrogen, and hydrocarbon dioxide, thus neurons lose their healthy shape and identity and become an amorphous mass—fragmented, disconnected, shattered. Despite this grim scenario, the process of deterioration in Alzheimer's is slow. A robotic helper that prompts those individuals who are hampered by their inability to recognize faces or names would experience an improvement in their lives if they could be trained to use a robotic helper that compensates for their forgetfulness.

4.5 FACIAL RECOGNITION PSYCHOPATHY IN PRISONER POPULATIONS

> *I have spent a lot of time locked up, but. I have never served time. because I have made that time serve me, and I have never been able to find enough of it to do all the things that I wanted to do.*
>
> —Robert Stroud, Lifer Number 594 (qtd., Gaddis 264)

Theoretically, I postulate that serial killers, including Ted Bundy (1946–1989) and the Green River Killer, keep slaying the same woman over and over again and that they obsessively and compulsively murder girls and women because they bear some resemblance to a girl or woman who traumatized them. They exhibit traits of paranoid schizophrenia, because they appear to be above average in intelligence and appear to be living normal lives, except for this perplexing flaw in their personality. In fact, I actually (unknowingly) met the Green River Killer at a bus stop where I was carrying a dozen books to return to the library. He said, "Would you like to go for a ride in my car, or rather, my automobile," because, he mumbled, "You look like Mary Jane (https://www.findagrave.com/memorial/6893247/mary_jane-m_-malvar), or Kimi-Kai (https://www.findagrave.com/memorial/6893275/kimi_kai-pitsor), and Pammy (https://www.findagrave.com/memorial/6892528/pammy-annette-avent). You sorta look like Lisa (7 https://www.findagrave.com/memorial/6892576/lisa-lorraine-yates), but she was blonde. Mostly, you remind me of Opal (https://www.findagrave.com/memorial/6892606/opal-charmaine-mills) because you are carrying all of those books." Disappointed, he kept talking until a detective, who was observing from across the street in front of Macy's, peacefully took him into custody, saying "I just want to talk to you." Much later, I read the front-page stories in the local newspapers, one of which eventually printed little photographs of all of the women for whom he had shown the police the burial sites. His victims did indeed resemble me. I know nothing of his background, but I would not be surprised if he had experienced a traumatizing situation somewhere in his past that caused him to continue to kill virtually the same person repeatedly. He told me and the detective as he walked away from me that he did not mind going to prison because he had thought of a goal: to be like the Birdman of Alcatraz. Robert Stroud (born January, 1890; died Seattle, 1963), convicted of homicide in 1909 was "a scientist and an international authority on bird diseases" (Gaddis 249; also see Stroud). Later, I understood, when I read front-page news stories, that the soft-spoken, polite gentleman was Gary Ridgway, whom I watched, without knowing his identity, as he was led away by the plainclothes detective, who acquiesced to his request not to use handcuffs, that he would walk peaceably with him on the crowded sidewalk.

4.6 SUPERPOSITION AND ENTANGLEMENT IN POE'S MYSTERY STORIES

Facial recognition psychopathy is characterized by a marked inability to express observable emotion (affect), and concomitantly, to recognize genuine emotion (cognition). Fearless dominance psychopathy is epitomized in Poe's depiction of the widower protagonist in "Ligeia," who gives a detailed account of his two marriages. Impulsive antisociality psychopathy is exemplified in Poe's portrayal of the gentleman gambler protagonist in "William Wilson," who feels he is being followed everywhere he goes by a man who looks just like him. Fearless dominance is indicated by "social dominance, stress resiliency, and thrill-seeking" and correlates positively with socioeconomic status and verbal intelligence" (Benning et al., 2005). The disconsolate widower in "Ligeia" is an upper-class social climber who exhibits fearless dominance psychopathy as he successfully wins the hearts and minds of two aristocratic women, who, in turn, consent to becoming his wife. Typically, "unrelated to child antisocial behavior and substance abuse," fearlessly dominant behavior is associated with "adult antisocial deviance" (Benning et al., 2005). In a clever attempt to excuse his unacknowledged desecration of the institution of marriage, the well-spoken monologist in "Ligeia" insinuates that he might have benefitted from Freudian psychoanalysis of his childhood when it all began; later, he brags about indulging in mind-altering drugs. His total failure to mention that he has defiled the sacrament of holy matrimony exemplifies adult antisocial deviance. The compulsive gambler in "William Wilson" typifies impulsive antisociality associated with "rebelliousness, impulsivity, aggression, and alienation" and correlates negatively with socioeconomic status and verbal intelligence and is positively related to "child antisocial deviance and substance abuse as well as adult antisociality" (Benning et al., 2005). Vaguely aware of his deficit in facial recognition, he recounts his childhood, adolescence, and early adulthood, making an effort to account for his unorthodox lifestyle.

The narrating protagonists in both "Ligeia" and "William Wilson epitomize "successful psychopaths," defined by an American pioneer in the field of psychopathy, H. M. Cleckley, who served as the psychiatrist for the prosecution at the trial of serial killer Ted Bundy in 1979, as individuals who "possess features of psychopathy, but are able to function adaptively in society and avoid negative encounters with law enforcement" (Cleckley, see Wilson 3). My focus in the present study is on male protagonists, but the psychopathy of deviant behavior based on psychological face recognition deficit is a rapidly growing research area not only in studies of men, but also of women (see Dolan and Völlm; Eisenbarth, Alpers, Segrè, Calogero, and Angrilli; Lehmann and Ittel; and Verona and Vitale), as well as of children (see Jones et al., 2009; Marsh et al., 2008; McCown, Johnson, and Austin, 1986; Stevens, Charman, and Blair, 2001; Walker and Leister, 1994; Zabel, 1979).

4.7 FACIAL RECOGNITION AND EMOTION PROCESSING IN POE'S "LIGEIA"

Significantly, we observe Lady Ligeia (LL) through the utterly romantic vision of the enthralled narrator. His description of Ligeia, cast in emotional language reflective of passionate devotion, indicates a great deal about his personality and character. Ligeia remains an ethereal figure, almost a product of his imagination. It is important, therefore, to notice the qualities he attributes to Ligeia and also the way he describes those qualities.

Although he does not rigidly compartmentalize her traits of character, he does present Ligeia as a paragon of perfection. His ideal image of Ligeia's "gigantic volition" (Poe, *Complete Works* II, 253) and her "infinite supremacy" in "all the wide areas of moral, physical, and mathematical science" (CW II, 254) contrasts sharply with his misguided will, intellect, and moral sense, particularly as exhibited by him in the second half of his narrative. Though he seems, for the most part, incapable of sound judgment, he possesses a kinetic, volatile, even a morally inspired imagination, which is, however, eclipsed by his countermanding will. On her death, Ligeia becomes, in his account of the heightened atmosphere during his deathwatch, an omnipresent force, whose moral purpose, however, he disregards. Conversely, despite his failure to discuss with any degree of insight his perceptual and moral shortcomings, he evinces, but bizarrely, latent awareness of his moral accountability, when he, in his bedside vigil, attempts by sheer power of his will to disinter angelic Ligeia by methodical displacement of Rowena.

"Ligeia" begins with the narrator traveling into the past to recollect when and how he met his first wife. Searching his memory in tones of mild perplexity and frustration, he confesses his inability to remember something very important to him, thus creating at the outset a sense of mystery, but also of uncertainty and confusion. His psychological state of temporal suspension having formed an atmospheric backdrop, he introduces his main object of concern, Ligeia, the gravitational center of his story. He can recall neither her family name nor the exact circumstances of how he met her. Ligeia exists as a real person, but she is also an idealized image of an archetypal woman and he prefers to think of her as a dream creature who made a mysterious and lasting impression on his mind: "She came and departed as a shadow. I was never made aware of her entrance into my closed study save by the dear music of her low voice as she placed her marble hand upon my shoulder" (CW II, 249). His description of Ligeia foreshadows that of Lenore in Poe's celebrated poem "The Raven," in which the narrator is similarly located in a closed study where the dream-like encounter takes place, between idealized beauty, but juxtaposed with the concrete reality of death, evoked in the psychologically symbolic image of a raven perched upon the sculpted bust of Pallas Athena, Greek goddess of beauty and justice (Watanabe in *Inhabited by Stories*, 277–88). What remains vivid in the mind of Ligeia's widower husband is womanly personhood. Ligeia is tall, somewhat slender, and majestic in bearing. The details of her personal appearance, numerous, and scrupulously enumerated, are rendered not graphically with an eye to producing a photographic likeness, but poetically and impressionistically, to stress her otherworldly, rather than her physical, presence. Her invisible magnetism reminds him of "the radiance of an opium dream—an airy and spirit-lifting vision" (CW II, 249), which suggests mystical transcendentalism partially concretized in his comparison of her to a delicate ivory or marble art object.

Worthy of special note is his description of her face, which he discusses in the manner of an appreciative architect observing the structural design of a building. Poe's handling of this device is brought to its fullest development in work published the year after "Ligeia." Poe, in "The Fall of the House of Usher" (1840), depicts a sentient house that suffers under the same sort of deleterious atmospheric oppression as the melancholy narrator who, unknowingly, sees the process of his internal deterioration when he becomes lost in his contemplation of the stagnant tarn surrounding the house. The narrator in "Ligeia" compares the elegant, expansive features of Ligeia's face to the smooth, hard planes and surfaces of a chamber of classic architectural design: "I examined the contour of the lofty and pale forehead—it was faultless—how cold indeed that word when applied to a majesty so divine!—the skin rivaling the purest ivory, the commanding extent and repose, the gentle prominence of the regions above the temples; and then the raven-black, the glossy, the luxuriant and naturally-curling tresses" (CW II, 250). If Ligeia's forehead is flawless, majestic, and natural, how different from the decaying house of Usher, yet how similar the way in which Ligeia and the house of Usher—Roderick, Madeline, and the ancestral line of Ushers—are perceived by the narrators in both stories. In these two tales of terror, the narrating protagonists reveal in their descriptions of their societal environments projected facets of their own psyches. For instance, Ligeia's profile reminds the narrator of the "graceful medallions of the Hebrews" (II, 250) and perhaps also of wealth and power of the tribes of Israel which attributed their deliverance out of bondage as slaves to the Egyptian pharaoh to designation of them as the chosen people of God (Yahweh; also, Elohim). In Poe's "Ligeia," the narrator scrutinizes the formation of his wife's chin and finds the fullness and spirituality of divine beauty. Hers is "the beauty of beings either above or apart from the earth" (II, 251). His relegation of her to a supernatural realm from the time he first laid eyes on her is a symptom of his facial recognition psychopathy. His excessively exalted opinion of her assuages his guilt complex, for it relieves him of the burden of ethical and moral responsibility he would assume if he were to see her as a normal woman. But, instead, he elevates Ligeia above the norms of an average wife, thus obviating the necessity to respect her womanhood. His facial recognition deficit puts her into the domain of archetypal idealism so that he feels no obligation to treat her humanely. Thus, he robs his wife of her personhood.

Ligeia's husband shows that he is morally conscious of his reductive reclassification of his wife into a reified object, placing her on a pedestal of idolatrous worship, substituting spiritually generated adoration for respect as a valued human being. By far her most remarkable feature, the eyes of Ligeia are inaccessible, inscrutable, and even foreboding. It is the "*expression*" (II, 251) of her eyes that he is most anxious, but least able to describe precisely.

He has pondered endlessly, struggling to fathom the depths of her eyes, but, as with certain facts pertaining to her life, his memory fails him. He reports that he is often "*upon the very verge*" (II, 252), but full knowledge of their expression eludes his grasp: "Ah, word of no meaning! Behind whose vast latitude of mere sound, we entrench our ignorance of so much of the spiritual" (II, 251). After Ligeia has died, he seeks expression of such spirituality in the material world. He resorts, however, to a poetical enumeration of natural objects to construct "a circle of analogies to that expression": "Subsequently to the period when Ligeia's beauty passed into my spirit, there dwelling as in a shrine, I derived, from many existences in the material world, a sentiment such as I felt always aroused within me by her large and luminous orbs. I recognized it. in the survey of a rapidly-growing vine—in the contemplation of a moth, a butterfly, a chrysalis, a stream of running water. I have felt it in the ocean; in the falling of a meteor. I have felt it in the glances of unusually aged people. I have been filled with it by certain sounds from stringed instruments, and not infrequently by passages from books" (II, 252). Unable to recognize the emotions reflected in Ligeia's eyes, he provides an index of symbols which suggest that he glimpses a life-force that is discernible in the world of nature, yet resides in a spiritual domain. Circumventing specific reference to the cause of his wife's death, he enshrouds Ligeia in an aura of mystery. As Roy P. Basler observes, "Final knowledge of the secret of Ligeia's eyes is blocked by an obstacle deep within the hero's own psyche, and the insatiable imagination seeks for a realm of experience not sensual and moral and identifies Ligeia with the dynamic power and mystery of the entire universe" (Basler 54). In a skillful evasion of statements that may be self-incriminating, he places Ligeia on a scale of cosmic magnitude, elevating her out of consideration as a mortal being.

Having contemplated further guidance from Ligeia "through the chaotic world of metaphysical investigation" with the feeling that he "might at length pass onward to the goal of a wisdom too divinely precious not to be forbidden" he observes, "How poignant, then must have been the grief with which, after some years, I beheld my well-grounded expectations take wings of themselves and fly away!" (II, 254). His aesthetic distancing, employment of the subjunctive mood, and flight imagery subtly reflect self-division, vagueness, and subterfuge. His reference to "a wisdom too divinely precious not to be forbidden" is a sinister paradox, which suggests his melodramatically heightened, hence distorted, sense of good and evil. By his use of a poetic language of evasion, he unintentionally suggests a link between Ligeia's death and motives of which he is only partially aware.

His insensitive treatment of Ligeia and motive for murder are intensified by his facial recognition psychopathy, which is the causative factor behind his inability to respond to Ligeia when her face expresses fear and then sadness during her struggle for life. Studies show that psychopathic individuals with facial recognition deficiencies lack sensitivity to other people's fearful expressions (Blair et al., 2004). Neuroscientists find evidence, not limited to fear and sadness, but of pervasive emotion recognition deficits for facial and emotional expressions in psychopathy (Dawel et al., 2012). Ligeia's husband shows genuine respect, meandering between admiration and callousness; indeed, he straddles a line between non-criminal thoughtlessness and criminal cold-heartedness (Iria and Barbosa 2009).

Practically speaking, all that we learn of Ligeia's death is that Ligeia "grew ill" (II, 254) and that he "saw that she must die" (II, 255). Preoccupied with discovering the secret contained in the expression of her eyes, he claims the insight given by "length of years, and subsequent reflection" (II, 253) and reveals that the source of both his fascination and his frustration was in Ligeia's will to live, which was most evident when Ligeia was dying, breathing her last breaths: "Words are impotent to convey any just idea of the fierceness of resistance with which she wrestled with the Shadow. I groaned in anguish at the pitiable spectacle. I would have soothed—I would have reasoned; but, in the intensity of her wild desire for life,—for life—but for life—solace and reason were alike the uttermost of folly. Yet not until the last instance, amid the most convulsive writings of her fierce spirit, was shaken the external placidity of her demeanor. Her voice grew gentler—grew lower—yet I would not wish to dwell upon the wild meaning of the quietly uttered words. My brain reeled as I hearkened entranced, to a melody more than mortal—to assumptions and aspirations which mortality had never before known" (II, 255). Similarly, it is in Ligeia's dying that Ligeia's husband appears to gain a full appreciation of her love; again, he marvels at Ligeia's tenacious determination to live: "But in death only, was I fully impressed with the strength of her affection. For long hours, detaining my hand, would she pour out before me the overflowing of a heart whose more than passionate devotion amounted to idolatry. How had I deserved to be so blessed by such confessions?—how had I deserved to be so cursed with the removal of my beloved in the hour of her making them? But upon this subject I cannot bear to dilate" (II, 255–56).

The image of Ligeia detaining her husband just prior to her death appears in a faint though evocative echo in their last meeting. By the use of "blessed" and "cursed," the narrator means to suggest that these events, in particular Ligeia's death, were determined by the impassive whims of chance. A parallel juxtaposition of polar opposites, his rhetorical questions are important in that he refrains from pursuing the subject of his worthiness, or culpability, while insinuating that he is aware that he was in a grotesquely paradoxical, even a false, situation, and is either unable or unwilling to delve further.

Blocking paths to further disclosure by creating new avenues through obfuscating clouds of inspiration, the speaker directs our attention away from the concrete and material. He discovers the secret of Ligeia's eyes, paying humble tribute to the strength of her love, especially her love of life: "In Ligeia's more than womanly abandonment to a love, alas! All unmerited, all unworthily bestowed, I at length recognized the principle of her longing with so wildly earnest a desire for life which was now fleeing so rapidly away. It is this wild longing—it is this eager vehemence of desire for life——that I have no power to portray—no utterance capable of expressing" (II, 256). His wonderment at Ligeia's struggle to live is more than praise of her will; it is a prefiguration of the revivification at the end of his narrative. A eulogy for Ligeia, his protracted monologue is also an atonement and a justification for unacknowledged guilt.

The look in her eyes mirrors the force of her will to live during her struggle to fend off her husband's stranglehold, which is calculated to deprive her of the breath of life. He discloses that "she died" (II, 258). He renders Ligeia's death poetically, almost as a literary event. With her last breath, Ligeia reiterated the ominous formula: "*Man doth not yield himself to the angels, nor unto death utterly, save only through the weakness of his feeble will*" (II, 258). This enigmatic final pronouncement indicates that Ligeia saw in the intent gaze of her husband his ulterior motive; his determination to see her breathe her last breath is motivated by his desire to possess her material fortune. Thus, having given copious praise to Ligeia's attributes of love, beauty, knowledge, and spirituality, he, in a casual aside, discloses, "I had no lack of what the world calls wealth. Ligeia had brought me far more, very far more than ordinarily falls to the lot of mortals" (II, 258). He intends to imply that his grief was compensated for. Here, Poe plays upon the word "will," which Ligeia's husband repeatedly observed in his wife's eyes as the will to live. Ligeia's will to live only serves to redouble his efforts to do away with his wife so that he will receive the proceeds as the sole beneficiary named in Ligeia's will, i.e., last will and testament.

Since facial recognition psychopathy causes him to fail to speak about Ligeia's look of wild longing to live, so, too, he is unable and unwilling to acknowledge his role in Ligeia's death. His narrative discourse segues immediately from the death scene to recounting how his life changed after Ligeia died.

A rich widower, he purchases an old abbey in England. As literary critic Daniel Hoffman ironically states, "Although prostrate with grief he somehow finds the energy completely to redecorate the interior of this capacious structure" (250). Now that Ligeia is deceased, he moves perceptibly closer to expressing himself with unconscious reference to the kind of psychosymbolic correspondences that are salient features in "The Fall of the House of Usher," with its mirror imagery (Timmerman). Hoffman notes the structural design of "Ligeia," in which mind becomes identified with matter: "The exterior of the abbey and its situation are described with almost every adjective in the Gothic repertoire: wildest, least frequented, gloomy, and dreary grandeur, savage aspect, melancholy, and time-honored memories, utter abandonment, remote, and unsocial region, verdant decay. To this diction of the decadence wrought by ruin and time is joined the diction of decadence wrought by the human will" (Hoffman 250).

The narrator in "Ligeia" alleges that his confused state of mind after Ligeia died led him to enter rather suddenly into his marriage to Lady Rowena (LR). He reports that it was "*as if in the dotage of grief*" that he left the "dim and decaying city by the Rhine" and became "a bounden slave in the trammels of opium" (II, 258). He represses his guilty conscience and attributes his mental distress to being grief-stricken and addicted to opium, which are falsehoods, an integrated strategy symptomatic of his fearless dominance psychopathy.

Poe prepares readers for the climactic facial recognition scene, setting up a psychologically symbolic parallelism. While Poe's primary concern is to portray Rowena as a "vehicle," a foreshadowing of the revivification scene at the tale's conclusion, the widowed newlywed husband wants to reify Rowena similarly to the way he manipulated Ligeia. Prone to make false confessions of memory failure, confusion, reverie, and melancholy, he divulges that his wedding to Rowena occurred in "a moment of mental alienation" (II, 259). Moreover, he harbors a vague suspicion that Rowena's family permitted the marriage "through thirst of gold" (II, 259). He implies that Rowena married him for his money, but he fails to realize that his accusation is a projection of his own thirst for gold. Poe's subtext subtly suggests that the narrator in "Ligeia" is a serial uxoricide, a compulsive talker who inadvertently betrays his motive for murdering his two beautiful wives.

Apologetic for his slippery hold on important facts, he proudly displays his ability to provide a detailed description of Rowena's bridal chamber. The vivid picture he paints is not, however, merely descriptive. Nor is it vague and impressionistic. His account of the room he selected and designed is at once objective and subjective. Formerly an abandoned monastic retreat where men clad in black gathered together in mystical communion and religious worship, the bridal suite symbolically mirrors the groom's psychic struggle. In preparing the bridal suite, Rowena's husband exactingly and unconsciously arranged the color scheme to correspond with his remembered image of Ligeia. Unwittingly, he reveals subconscious motives both malevolent and benevolent in nature. The color black, associated traditionally with mourning and reverence, also invokes evil. Poe weaves the widower-bridegroom's unreliability as a storyteller into the narrative discourse as a conspicuous thread of sinister innuendo held taut by Poe, who probes the narrator's facial recognition psychopathy. When we analyze the subtext, we will discover an intricate form of duplicity. The narrator fails to respond to his revered image of goodness, Ligeia, in whose name he does away with Rowena.

His self-incrimination as a seriously flawed reflector of reality is complex. His monologue is charged with a peculiar ambivalence that may be traced to his equivocal status as an unreliable narrator who is "frustrated by a psychic flaw which he is aware of but does not understand" (Basler 56). Preferring to live amid a world of opium-engendered shadows and visions to the exclusion of existential reality, he attempts to appease his conscience and attends dutifully to Rowena's needs. He evinces latent awareness of his psychological dilemma with its inherent moral implications, but he fails to respond to cautionary signs which are filtered through a double screen of obsessive delusion and willful self-deception, which he perceives only vaguely as indications of Ligeia's presence and collusion.

Although Ligeia and Rowena represent opposing forces in his mind, including the ideal versus the real, the desirable versus the contemptible, the positive versus the negative, and the spiritual versus the material, both of these two women may be viewed as disguised conscience figures who are presented unwittingly by the narrator as projections reflecting his fractured moral sense. His duplicitous story also contains poetical evocations of Poe's criticism of the mentally disturbed, criminally insane narrator. Indeed, like the narrator in Poe's tale "The Sphinx" (1846), whose lack of perspective causes him to see an insect as a gigantic monster, the narrator in "Ligeia" suffers from a visual impairment traceable to the psychic disturbance known as facial recognition psychopathy. Ironically, the twice-widowed narrator portrays Ligeia as an indelible image of absolute goodness and he uses idolatrous imagery willfully as a barrier that prevents him from facing his wrongdoing.

While he readily admits that he is "sadly forgetful on topics of deep moment" (II, 259), he remembers perfectly the "architecture and decoration" of the bridal suite he shared with Rowena. He asserts that "there was no system, no keeping, in the fantastic display, to take hold upon the memory"; the disposition of the room is, in fact, determined by a psychologically regulated organizing principle. His description of the suite reflects his subconscious image of Ligeia and his relationships to his two wives. He unwittingly patterns his description to exhibit what he fails to confess. Ligeia's presence remains in his mind, not merely as a mournful memory but in a way similar to that in which the conscience figure pursues the narrator, an inveterate gambler, in Poe's doppelgänger tale "William Wilson." As the differing forms of projection suggest, the extent of his awareness in "Ligeia" is, if not significantly less, qualitatively different from that of Wilson, who at least feels he is being admonished by someone who resembles him in practically every way. Unlike Wilson's double, Ligeia is seen by her husband as neither conscience figure nor nemesis. Nevertheless, as in "William Wilson," the protagonist in "Ligeia" claims to encounter a supernatural being, which confirms a semiconsciously plotted passage into madness, hence moral darkness, motivated, in part, by a fractured moral sense. Its psychodramatic properties revelatory of the narrator's tormenting preoccupation with Ligeia, the bridal death chamber is located in "a high turret of the castellated abbey," and like Ligeia's forehead, is "of capacious size." Like the narrator, the room has only one view: "Occupying the whole southern face of the pentagon was the sole window—an immense sheet of unbroken glass from Venice—a single pane, and tinted of a leaden hue, so that the rays of either the sun or moon, passing through it, fell with a ghastly luster on the objects within" (II, 259).

The beautiful eyes of Ligeia, now dead of some unnamed disease, have, in the narrator's mind, been reduced to the ominous number, one, just as the narrator in "The Black Cat" (1843) tears out Pluto's eye, which forecasts the hideous murder of his wife. Above this large window is "the trellice-work of an aged vine" (II, 259). In his attempt to approximate the expression in Ligeia's eyes, the narrator began with "the survey of a rapidly-growing vine" (II, 252). Commensurate with the "immense" (II, 253) learning of Ligeia is the ceiling, which is "excessively lofty, vaulted," but also "elaborately fretted with the wildest and most grotesque specimens of a semi-Gothic, semi-Druidal device" (II, 259). From the central and innermost recess of the vaulting "depended. a huge censer" of gold "with many perforations so contrived that there writhed in and out of them, as if imbued with a serpent vitality, a continual succession of particolored fires" (II, 259–60). Consumed by his passionate longing for Ligeia, the narrator fashioned a room-sized arabesque, an expressionistic embroidery where ornate and emphatic forms trace the contorted movements of his self-deception and evil-minded guilt.

Jung observes that a lowly swineherd vainly tries to reach a "high-born princess" that represents "higher consciousness" yet fails because her image is the "feminine counterpart" to his "masculine consciousness"; thus, she represents both his "subconscious" and "superconscious," and when he reaches her, he "stands as high above the 'subconscious' as above the earth's surface" (Jung 96). Jung concludes that the swineherd gets "caught in the upper world" and "remains lost in paradise," which shows he has a malfunctioning moral sense, too weak to override his malevolence, yet strong enough to trigger his being "spellbound" *as* a "punishment for his transgression" (Jung 97). In "Ligeia," the narrating widower hovers in a netherworld where he is held spellbound by the projected animus image which he loves but eradicates.

In her death-bed recital, Ligeia prophetically announced the theme for the involuted, monodramatic, psychomimetic design: "That motley drama!—oh, be sure/It shall not be forgot!/With its Phantom chased forever more,/By a crowd that seize it not,/Through a circle that ever returneth in/To the self-same spot,/And much of Madness and more of Sin/And Horror the soul of the plot" (II, 256–57). Woven into the story's texture are grotesque and distorted images, arising, though not recognized by the narrator, from the depths of his unconscious mind, eccentric imagery harkening back to the biblical garden of Eden and the tempting of Adam and Eve by an eloquent and malevolent serpent.

Framing this vivid, dramatic, contrived picture of the bridal chamber, replete with oblique allusions to Ligeia, are a canopied couch "sculptured of solid ebony," "black granite" in every corner and heavy gold drapery "spotted all over, at irregular intervals, with arabesque figures, about a foot in diameter, and wrought upon the cloth in patterns of the most jetty black" (II, 260). The narrator reveals that to anyone who enters the room, the arabesque figures "bore the appearance of simple monstrosities; but upon a farther advance, this appearance gradually departed." Upon penetrating the chamber, a visitor, simply as a result of the change in viewpoint, "saw himself surrounded by an endless succession of the ghastly forms which. arise in the guilty slumbers of the monk" (II, 260). The display is made even more striking by the showmanship of the narrator: "The phantasmagoric effect was vastly heightened by the artificial introduction of a strong, continual current of wind behind the draperies—giving a hideous and uneasy animation to the whole" (II, 260–61). Basler observes, "Although his narrative avoids anything which suggests a physical attempt at murder, there are unintentional confessions of deliberate psychological cruelty in the macabre furnishings of the apartment and in the weird sounds and movements designed to produce ghostly effects" (58–59). But the chamber is also a fascinating expressionistic display of the narrator's uneasy remembrance of Ligeia, her sudden death, and her husband's deeply buried feelings of guilt. It is within the realm of possibility that the narrator suspects that Ligeia died by reason of his own considerably less perfect nature. For example, he admits that he "should not have doubted" her love (II, 255). In any case, after her death, his baser instincts seem to overpower all that Ligeia stands for. Nonetheless, his description of the bridal chamber and the final scene indicate that he, like the adventuresome gamester in "William Wilson," subconsciously plots the return of his dream vision, of his conscience. That his willful neglect of Rowena subverts the very ideal he seeks is a consideration he is unable, certainly unwilling, to face. He declares that in this bridal chamber, he passed "unhallowed hours" with Rowena, whom he "loathed. with a hatred belonging more to demon than to man" (II, 261). Cowed by this unpleasant feeling, he abruptly changes the subject: "My memory flew back, (oh, with what intensity of regret!) to Ligeia, the beloved, the august, the beautiful, the entombed" (II 261). Instead of exerting a benevolent influence, his idealization works in him a macabre metaphysical death-wish, a compulsion to startle himself to oblivion with an imagery of pure, white nothingness, a blinding image he names "Ligeia."

In the final episode, he obsessively recounts with precision and apparent lucidity his progressive movement toward madness. His is a rapt, almost blissful retreat from reality. In moments of brief hesitation, however, the increasingly insistent tone and rhythm of the narrative turn back upon themselves, thus marking his profound confusion, his interior oscillation between falsehood and forgotten truth, false happiness and unbearable woe.

Although he presents the deathwatch as a successful attempt to transcend the bounds of reality, it culminates in the supposed revivification of Ligeia, at the same time it obliquely offers clues, unobtrusively woven into his discourse by Poe, who remains aloof and refrains from making editorial comments. These clues illuminate the narrators almost completely suppressed moral sense. With Rowena's apparent transformation, Ligeia's prophecy is fulfilled: "Out—out are the lights—out all!/And over each quivering form,/The curtain, a funeral pall,/Comes down with the rush of a storm,/And the angels, all pallid and wan,/Uprising, unveiling, affirm/That the play is the tragedy, 'Man,'/And its hero the Conqueror Worm" (II, 257). The preset stage seems to take on a life of its own. The eerie shadows and menacing whispers of the wind terrorize Rowena, but the writhing forms act as accomplices to her husband, who is intent upon seeing Ligeia. He becomes aware of a presence, "a faint, indefinite shadow of angelic aspect," then he hears a "gentle foot-fall upon the carpet." In the next moment, he reports, "I saw, fall within the goblet, as if from some invisible spring in the atmosphere of the room, three or four large drops of a brilliant and ruby-colored fluid" (II, 263). Since Rowena obediently swallowed the wine, the narrator states reassuringly that he probably imagined something was amiss. He does, however, venture a confession: "Yet I cannot conceal it from my own perception that, immediately subsequent to the fall of the ruby-drops, a rapid change for the worst took place in the disorder of my wife" (II, 264). It is certainly possible, as Basler argues, that "This is the wish-illusion that not he but the ghost of Ligeia. is preying upon the distraught and febrile body of Rowena" (59). However, the presence of this shadow, unquestionably an allusion to Ligeia, may also indicate his vague awareness that he is engaged in wrongdoing.

The remarkable presence may very well indicate that Ligeia is there, much in the same way that Wilson's double is always there, to administer a warning to the narrator. Thus, the projected shadow symbolizes evil intent—to poison Rowena—but also partial moral consciousness. At the core of his being reside both awareness and will to self-deception. Tipping the balance is his disordered imagination. At "midnight, or perhaps earlier, or later" (II, 264), he imagines he hears a "sob, low, gentle, but very distinct. from the bed of ebony—the bed of death" (II, 264) and supposes this to be a sign that, he surmises, "My soul was awakened within me" (II, 265). In this instance, "soul" means "imagination," and his statement indicates a psychic recession as he continues to seal himself off from the real world.

Despite ostensible attempts to show a concern for Rowena, he becomes increasingly distressed and fearful when Rowena, still as Rowena, seems to regain her strength. To give the impression that he is fully aware of a moral obligation to Rowena, he reports that on two occasions, duty impelled him to care for her, but his manner of expression betrays his actual wish: "Yet a sense of duty finally operated to restore my self-possession. I could no longer doubt that we had been precipitate in our preparations—that Rowena still lived" (II, 265). Periodically disappointed in his wish to see Ligeia alive, and concomitantly Rowena dead, he is, in effect, content when Rowena seems to collude with him and lapses into "a wanness even more than that of marble"

(II, 265), for she now bears a closer resemblance to Ligeia, whom he wishes to will back to life. Signs of warmth in Rowena result in an abatement in his “passionate waking visions of Ligeia” (II, 265) and seem to spark a sense of responsibility in him: “I listened—in extremity of horror. The sound came again—it was a sigh. Rushing to the corpse, I saw—distinctly saw—a tremor upon the lips. I felt that my vision grew dim, that my reason wandered; and it was only by a violent effort that I at length succeeded in nerving myself to the task which duty thus once more had pointed out” (II, 266). He summarizes, or foreshortens, subsequent steps in the “hideous drama of revivification” in which he, strategically stationed in the midst of wind-blown drapes and dancing arabesque figures, but also rigid with fear, is “a helpless prey to a whirl of violent emotions” (II, 267). When the enshrouded figure finally arises, her husband, whose real concern is that he has gone through the ordeal of surveillance over a woman who refuses to die, questions his own sanity, protesting that he is caught in a “mad disorder” of thoughts and is, outwardly, “paralyzed” and “chilled. into stone” (II, 267–68). As the tottering figure approaches, he, apparently to demonstrate his feeble hold upon reason, but in a tone at once triumphant and hysterical, dramatically repeats a series of rhetorical questions designed to elicit belief in the supernatural.

If his sinuous sentences writhe like the “crawling shape” of the Conqueror Worm, they also subtly announce his sin and the inevitability of death. The appearance of Ligeia as a supernatural being signals his loss of existential consciousness, hence of conscience. The concluding scene in the story shows by indirect implication that he represents not an Adamic man, but a “Man” who falls into the darkness of his obsessive-compulsive delusions. Like the “mimes, in the form of God on high,” of whom he speaks, the narrator is a puppet who acts “At bidding of vast formless things/That shift the scenery to and fro, /Flapping from out their Condor wings/Invisible Wo!” (II, 256). In the end, the stage set in an arabesque design of black and gold, arranged in apparent confusion, the monologist sees, in his fantastical imaginings, the wind-blown raven-black hair of Ligeia merge with and displace the golden tresses of Rowena. Hideously interwoven into the narrative, the black and the gold represent, then, the warring factions in the narrator’s muddled mind. In the final moment of the fable, the storyteller, his mind effectively torn asunder from his existential body, sees, in the etherized atmosphere, Spirit individualized: “There streamed forth, into the rushing atmosphere of the chamber huge masses of long and disheveled hair; it was blacker than the wings of the midnight!” (II, 268). His comparison may come closer to describing what he actually saw than he realizes. He thinks he willed Ligeia back into existence or that she willed herself back to life. But either way, it is self-delusion, belief in a wish-fantasy. Yet, he feels exposed, as a mad scientist realizing he is a two-timing scoundrel. His claim of an apocalyptic vision may well be authentic; in conceiving it, he momentarily shatters his connection to his insane and evil scheme.

Subtly, Poe strikes a satirical blow against extravagant retreats into realms of abstraction, fashioned in accordance with the prescriptions of Romanticism, including the supernatural, transcendentalism, and Gothicism, which are forms of romantic excess. At the same time, Poe conveys a vivid impression of his sense of a perilous encounter with death. This is one of Poe's most intensely rendered themes. Daniel Hoffman declares that "Death is personal extinction, the obliteration of this particular bundle of sensations and memories, and therefore terrifying. Death is also deliverance from the memories and sensations in which this particular person, this particular combination of atoms divided from the unity whence they came, is imprisoned—and thus death is welcome" (258).

But in "Ligeia," the widower's death-defying attitude constitutes a rather different kind of personal extinction and deliverance. The revivification of Ligeia, contingent upon Rowena's death, is a partial obliteration of existential limits and a welcome deliverance from moral responsibility. "Ligeia," which Poe considered "his finest tale" (Fisher 5), is more than a sensational tale of the supernatural told by a madman. It is a profession of belief in the supernatural that originates not in opium, the miraculous, or insanity, but in willful, yet cowardly self-deception. Psychoethically, the narrator conjures a death-in-life condition. His isolation and imprisonment are both symptoms, and an image, of self-delusion. Terror, perhaps augmented by a repelling sense of guilt, and sublimity, ironically presented by Poe as an exaggerated sense of the ideal, are intertangled. Not quite blinded by his romantic idealism, the narrator, insinuating that Ligeia's ghost poisoned Rowena, and presenting the made-up or imaginary transformation of Rowena as a triumph of the supernatural, finds deliverance in the willful, though not necessarily conscious, perhaps the semi-conscious superposition of guilt and innocence, of death and life. Ligeia's startling appearance at the end of the story, as with that of Wilson's double, not only confirms the widower's evident deterioration into madness, but also evokes the moral conflict, the duplicity that is at the heart of the monologue. For the morally confused narrator, Ligeia is a kind of flawed talisman. She represents at once a vaguely perceived moral imperative and a supernatural license to poison Rowena. Paradoxically, his rigid allegiance to Ligeia seems to prevent him from acting upon the ideals he says she inspires in him. Thwarted by fears and obsessions, the narrator in "Ligeia" fails to appreciate fully the goodness he is only too certain he sees in Ligeia. His facial recognition psychopathy extends beyond any visual impairment to his eyesight and is a pervasive aspect of his personality and character. Poe's literary artistry veils the serial wife killer's guilt, paradoxically, in words spoken by a male protagonist who feels compelled to speak. Goaded by unacknowledged guilt, he glimpses the truth, but he supplants his own self-image as a killer who stalks wealthy women motivated by covetousness. An atavistic avatar of Faust, the widower, symbolizes insatiable lust for upward mobility. But the higher the ruthless social climber rises, the greater his facial recognition psychopathy because he no longer has personhood as a sustainable member of human society.

4.8 NEUROCOGNITIVE PERCEPTION AND DECISION MAKING IN POE'S "WILLIAM WILSON"

In "William Wilson," Poe ironically shows that a concept of conscience and a belief in conscience do not perforce lead one to act or speak in good faith. In a death-bed confession, the narrator presents himself as "the slave of circumstances beyond human control" and "a victim to the horror and the mystery of the wildest of all sublunary visions" (Poe, *Complete Works* III, 300). Narrated in the past tense, the story is told from the perspective of a self-styled tragic hero whose "present purpose" is "to assign" the "origin" of "the sudden elevation in turpitude" that marked the beginning of the unfortunate "epoch" in his life, his "later years" (CW III, 299). If his melodramatic monologue is taken at face value, the monologist appears to have been forced to murder his conscience, precipitating a life of "unspeakable misery" and "unpardonable crime" (CW III, 299). In the course of the narrative, the narrator unwittingly reveals how he has, through willfulness and self-delusion, perpetrated the "temptation" (CW III, 300) and fall he imputes to his "tormentor" (CW III, 322, 323), the "accursed villain" (CW III, 324), William Wilson. In his consistent denial of identification with the alienated portion of his selfhood, namely conscience (perceived vaguely, incompletely, yet intensely by the narrator as superposed moral imperatives and ethical duties and obligations), he betrays his conscience (evocatively defined by Poe's subtext as full moral consciousness). Conscience is not only an alter ego but also to be understood according to the French meaning of *la conscience*, to include consciousness, moral sense, scrupulousness, and sincerity.

The first-person narrator in “William Wilson” proves to be a model of facial recognition psychopathy, which manifests predominantly as impulsive antisociality. His dominant personality traits include rebelliousness, impulsivity, aggression, and alienation, which correlate negatively with his socioeconomic status and verbal intelligence, and found to be positively related to childhood antisocial deviance that led to substance abuse and antisociality during his adulthood. By his admission an attempt to elicit “the sympathy” of his “fellow men” (CW III, 299–300), his narrative, told in the form of a self-centered monologue, is, ironically, a self-betrayal. With each word he utters, he unintentionally mocks the self-image he proffers. Ultimately, the narrator-monologist is the victim of his blighted awareness. Despite his claim to moral hindsight, he construes an excursion into the supernatural as a tragic moment of moral insight. His deficient facial recognition psychopathy, which affects his observable behavior, prevents him from seeing himself as he is. Thus, impulsive antisociality and self-alienation are inextricably intertwined. He projects his inability to understand himself emotionally as he adopts a rebellious attitude toward his social milieu. His defensive impulse to protect his fragile sense of selfhood is observable as aggression. His profession of gentleman gambler empowers him to exact a toll calculated to compensate him for being victimized by society. He is a more sophisticated model of facial recognition psychopathy than the serial uxoricide in “Ligeia” because he consciously and intentionally seeks to take revenge against society for failing to prevent him from becoming a social pariah. As the author of “William Wilson,” Poe obliquely shows a sympathetic understanding of the protagonist, who provides factual data to construct a medical history. All that remains is diagnosis and treatment that will be appropriate to the needs of this gentleman gambler who is disturbed by his symptoms without having access to medical and public health professionals to provide him with palliative care to alleviate his distress as a patient with facial recognition psychopathy whose reportage reveals him to be a victim of impulsive antisociality syndrome.

Weighted down by despair, yet at pains to describe in detail the sequence of events that led to his collapse, the narrating monologist does not appear to be aware of the significance of his story. Thus, he portrays himself as a fun-loving rake who was goaded by Wilson into killing Wilson, who turns out to be, paradoxically, both conscience and the cause of the narrating monologist’s subsequent criminality. Viewed by the narrating monologist as a persecutory and ubiquitous phantom that incessantly betrayed him, Wilson seems to have tracked the narrating monologist with the plot and persistence of Monsieur C. Auguste Dupin, the amateur sleuth in Poe's "Murders in the Rue Morgue" (1841), who uses scientific methodology to solve the murders of two women in Paris by an orangutan captured by a British sailor in Borneo (Indonesia), the largest island in Asia. Even as he reviews his experience in retrospect, Wilson fails to consider fully his namesake's motives and ultimate purpose.

Not realizing that his repudiation of moral authority is based on an exaggerated, distorting, hence false respect, the unreliable narrator does not resolve a fundamental issue, his double's *raison d'être*. It is Poe who reveals indirectly, through psychologically symbolic evocation, the answer to the narrating monologist's rhetorical question, "But who and what was this Wilson?—and whence came he?—and what were his purposes?" (CW III, 315, 321). Obliquely, Poe implies that Wilson's double owes his existence to the narrating monologist's compelling, though suppressed, moral awareness, which is paired with a psychological need for a scapegoat to be credited with the guilt, and concomitantly, the sense of responsibility, the narrating monologist disclaims in his petulant assertion of his "natural rights of self-agency" (CW III, 322).

Protecting his position by giving a false impression at the very outset, the narrating monologist strikes the pose of a Byronic hero who shows a reckless disregard for money. Forced by far-reaching disrepute and a disinclination to sully "the fair page," he conceals his "real appellation" under the guise of a pseudonym, "a fictitious title not very dissimilar to the real" (CW III, 299, 305). His opening line, "Let me call myself, for the present, William Wilson" (CW III, 299), may call to mind the self-introduction and story of the narrating monologist who begins simply, "Call me Ishmael" (Melville, *Moby-Dick* 1). Herman Melville's treatment of pursuit and obsession in Moby-Dick (1851) is comparable to Poe's highly concentrated probing of personality in "William Wilson." Whereas Melville explores dramatically the metaphysical implications of an epic quest, Poe probes the psychological and moral ramifications of a quest that culminates in unwitting self-betrayal. Melville presents the dramatized first-person narrator Ishmael sympathetically recording the tragic quest of the obsessed hero, Captain Ahab. Ishmael is the expressive, compassionate voice, while Ahab is all silence and metaphysical suicide in action. By contrast, Poe's narratological strategy enables the narrator, Wilson, who is also a protagonist obsessed with wrongdoing, to describe unsympathetically the dogged pursuit and silent campaign waged by a specter of his conscience, who is armed with the idea of inculcating a sense of moral obligation.

A close comparison may nonetheless be drawn between the Ahab versus Moby Dick relationship and that of the bad Wilson who retreats from the putatively good Wilson. Although the pursuit patterns are antipodal, the juxtaposition of these patently different quests, the one for wrathful vengeance, the other for the purpose of issuing a moral warning, illuminates what may be considered the good Wilson's flaw; his single-minded compulsion to expose the bad Wilson is not very different in quality from the monomaniacal determination of Ahab as he seeks to punish a sperm whale for defending itself against the death-dealing harpoons launched by the *Pequod* ship's company. Although Ahab's quest is solipsistic, in the context of Melville's novel, Ahab is, after all, chasing a real whale, which may, of course, be interpreted realistically and symbolically. In contrast, the character named in the title of Poe's "William Wilson" is, in actuality, a compression and crystallization of inchoate consciousness, fragments unconsciously organized not a coherent whole, a human form, perceived by Wilson as a ghost-like presence embodying traits and principles consciously rejected by the narrating monologist, yet ingrained deeply in his unconscious mind. Both Melville and Poe comment poetically on the adverse results and the self-destructive effects of action that is motivated by the irrational drive of obsession. Ahab, in effect, sacrifices himself and an entire ship's crew, except Ishmael. Poe's protagonist balances precariously on the rim of a bottomless well (pit of death and the unknown) and almost gets sliced down by an impersonal swing of the blade (pendulum of chronological time). Like Ahab, Wilson chooses to affirm his selfhood in a self-destructive way. He appears, like Ishmael, to be a survivor.

Moored in extravagant self-pity and self-aggrandizement, Wilson laments what he has become: "Oh outcast of all outcasts, most abandoned!—to the earth art thou not forever dead? To its honors, to its flowers, to its golden aspirations?—and a cloud, dense, dismal, and limitless, does it not hang eternally between thy hopes and heaven?" (CW III, 299). Employing imagery that helps to project his adopted pose, Wilson objectifies and depersonalizes aspects of his character that he is unwilling to acknowledge. Ironically, this attempt to take distance from himself is self-incriminating. The imagery comprises melodramatic displays of figurative language, but also self-revealing symbolism generated by his facial recognition psychopathy. Aware of his impulsive antisociality, he vents his frustration by monologizing. Thus, Poe anticipates the psychotherapeutic methodology associated with the Austrian neurologist and founder of psychoanalysis Sigmund Freud (1856–1939). At this point, narrating monologist Wilson does not yet name his double; instead, he finds metaphoric expression for vague, preconscious thought and alludes to his nemesis as a dark "cloud," but also as a softening "shadow" (CW III, 299). Fortifying his position through melodramatically inflected rhetoric, he implies that the source of his moral turpitude and suffering lies outside himself. Because of this external force, he reports, "From comparatively trivial wickedness I passed, with the stride of a giant, into more than the enormities of an Elah-Gabalus" (CW III, 299). Intelligently, with strategically pitched calculation, he uses hyperbole so that his self-comparison to a cruel and depraved Roman emperor makes his infractions appear nonthreatening. His suggestion that he underwent a dramatic transformation is misleading. His sententious, inflated style and expression betray a self-defeating doubleness. Though he aspires to such ideals as honor and heaven, the narrating "I" extends his career of prankish play, card sharper, wining, and wooing by playing the role of a tragic hero, jaded by a life of unparalleled crime and suffering.

Donning the grotesque double mask of a self-righteous villain, he intends to show that murdering his conscience was a justified act of self-defense, fraught with unforeseen and tragic repercussions. Although he ascribes a conventional moral meaning to the pattern of events he recounts, he designates as first cause the single moment wherein he was tyrannically forced to yield to temptation. Foreshadowing the end of the tale and capitalizing on what he sees as the sudden, fatal moment, he divests himself of all blame, observing that "Men usually grow base by degrees. From me, in an instant, all virtue dropped bodily as a mantle. What chance—what one event brought this evil thing to pass, bear with me while I relate" (CW III, 299). He claims his innocence to anyone willing to listen. The "one event" to which he refers reveals the extent to which he unconsciously identifies with his double. In the last confrontation, he, enraged, stabs his double, who, for some reason, fails to resist. In an ambivalent, patently ironic reversal, his double asserts, "'You have conquered, and I yield. Yet henceforward art thou also dead—dead to the World, to Heaven, and to Hope! In me didst thou exist—and, in my death, see by this image, which is thine own, how utterly thou hast murdered thyself'" (CW III, 325). Set in quotation marks to show that he intends to quote his double, yet echoing his own capitulation, he dramatizes his duplicitous role-playing and intricate self-deception.

His facial recognition psychopathy boomerangs such that he perceives his alienated moral sense as a projected mirror image. Thus, his consciousness repulses his moral sense by projecting this facet of his ontological being in the form of a doppelganger, a double who is like a biological twin. The psychological significance of this defense mechanism is that his character is flawed by an unwillingness to benefit from the knowledge contained in his consciousness, yet remains unprobed. Poe invites his readers to consider the meaning of this story about a man who claims he murdered his conscience.

Poe anticipates current research on facial recognition psychopathy in basing the central theme in "William Wilson" on the philosophical dictum "Know thyself," promulgated by Socrates (469 BC–499 BC). In the twenty-first century, researchers in facial recognition psychopathy may study Poe's "William Wilson" as a tale of mystery and imagination that shows how knowledge and understanding of facial recognition psychopathy illuminate the malfunctioning of a murderer's mental processes, in particular how the inability to recognize faces may be linked to lack of self-knowledge. Deficits in facial recognition keep individuals from learning to behave normally in social situations. If such individuals do not recognize the faces of persons whom they encounter in their circle of relatives, friends, and acquaintances, they may also be unable to recognize themselves in a mirror, literally and figuratively.

Poe has the protagonist in "William Wilson" provide a biographical sketch, which makes it easy for us to place ourselves in the position of researchers charged with the task of diagnosing the ailment that motivates Wilson to tell his story. Whether Wilson speaks in a medical examination room or a court of law, he pleads that he is innocent because of his genetic predisposition to be wicked. He entreats us to "seek out. some little oasis of fatality amid a wilderness of error" (CW III, 300). He presents his major flaws in character as an inevitable outgrowth of his heritage: "I am the descendant of a race whose imaginative and easily excitable temperament has at all times rendered them remarkable; and, in my earliest infancy, I gave evidence of having fully inherited the family character. As I advanced in years, it was more strongly developed; becoming, for many reasons, a cause of serious disquietude to my friends, and of positive injury to myself. I grew self-willed, addicted to the wildest caprices, and a prey to the most ungovernable passions" (CW III, 300). "Steeped in misery" (CW III, 301), he finds relief in his rambling narration of apparently trivial details. There are many references to sleep, meditation, and deeply imprinted patterns of thought and feeling. These subjective states find objective expression in his narration of lingering impressions that transport him from stark reality to a shadowed spiritual realm. Counterbalancing yet complementing these images evocative of a vast inner universe are concrete images of imprisonment and enclosure. These embryonic images, suggestive of a naive religiosity associated with a sense of personal confinement, will be individualized, to use a term from *Eureka* (1849), Poe's scientifically inspired cosmological poem, in the form of Wilson's double.

Recalling as a lost paradise the "misty-looking village" of his boyhood, he experiences once again the "refreshing chilliness of its deeply-shadowed avenues" and he thrills anew "with undefinable delight, at the deep hollow note of the church-bell, breaking, each hour, with sullen and sudden roar, upon the stillness of the dusky atmosphere in which the fretted Gothic steeple lay imbedded and asleep" (CW III 301). Poised against this "dream-like and spirit-soothing" image of measured stillness is an image of imprisonment: "The grounds were extensive, and a high and solid brick wall, topped with a bed of mortar and broken glass, encompassed the whole. This prison-like rampart formed the limit of our domain" (CW III, 301). Already, we have, as he avers, "the first ambiguous monitions of the destiny which afterwards so fully overshadowed me," he says (CW III, 301).

He builds on this dramatic statement and his preceding descriptions, verbally painting a striking picture of his school's principal. His perception of an inconsistency in the pastor is reflective of the schism in his own character: "With how deep a spirit of wonder and perplexity was I want to regard him from our remote pew in the gallery, as, with step solemn and slow, he ascended the pulpit! This reverend man, with countenance so demurely benign, with robes so glossy and so clerically flowing, with wig so minutely powdered, so rigid and so vast,—could this be he who, of late, with sour visage, and in snuffy habiliments, administered, ferrule in hand, the Draconian laws of the academy? Oh, gigantic paradox, too utterly monstrous for solution!" (CW III, 302). Still identifying with his adolescent perception, indeed transforming it into melodrama, he unwittingly reveals himself. His exaggerated descriptions of the regally attired pastor he saw from a distance and the "sour visage" he encountered at close range indicate his inability to reconcile appearance and reality, the accouterments or outward look of authority and the actual administration of authority. His perception of an inconsistency in the pastor, seen first as an august spiritual representative, then as a villainous truant officer, reflects his own internal discord. He considers the pastor a "gigantic paradox," an epithet that more fittingly describes the speaker. It is evident that facial recognition psychopathy manifests as a self-projection of his disintegrated core, i.e., alienation of moral conscience from his consciousness of being a member of human society.

His double, like his image of the pastor, reflects his disproportionate sense of reverence with its self-contradictory rebellion. He considers the pastor's enforcement of the rules of the academy an unwelcome interference with his will. Yet, the schoolmaster awakens his "spirit of wonder and perplexity," stirring his profound and confused conception of the very principles of moral action. In describing his double, he again evinces an ambivalent attitude in an unintentional self-betrayal. Hoffman explains Wilson's paradoxical nature in these terms: "If Wilson's double is his conscience, he is also his Imp of the Perverse. Which is to say that each half of the split ego has its own Imp of the Perverse—Wilson himself is such an Imp to Wilson, and the first Wilson reveling in obliquity in acquiescence to a deep impulse in himself which outrages the moral imperative represented by Wilson[2]" (Hoffman, 213). The projected conscience figure is flawed to the degree the projecting consciousness is flawed. The unconscious glorification of conscience is equivocated by a passionate rejection of its too keenly felt imposition.

Reversing Hoffman's attribution of perversity against conscience, we observe that Wilson is partially aware of the presence of a benevolent moral imperative: "In his rivalry he might have been supposed actuated solely by a whimsical desire to thwart, astonish, or mortify myself; although there were times when I could not help observing, with a feeling made up of wonder, abasement, and pique, that he mingled with his injuries, his insults, or his contradictions, a certain most inappropriate, and assuredly most unwelcome affectionateness of manner. I could only conceive this singular behavior to arise from a consummate self-conceit assuming the vulgar airs of patronage and protection" (CW III, 306). He intimates that the pastor is linked to vague memories of his father, who similarly tried to teach right from wrong, good from evil. Following a logical line of reasoning, he cannot admit that men such as his father and the pastor were prompted by love to punish him for his bad behavior.

In his attempt to understand why he is being harassed by his double, he associates morality with religion, and by extension, Wilson with the pastor. His double, like the pastor, whose step is "solemn and slow" and countenance is "so demurely benign," is imbued with "unassuming and quiet austerity" (CW III, 307). Disturbed by his observation of praiseworthy attributes in his double, he attempts to analyze systematically the feelings his double arouses in him: "It is difficult, indeed, to define, or even to describe my real feelings towards him. They formed a motley and heterogeneous admixture;—some petulant animosity, which was not yet hatred, some esteem, more respect, much fear, with a world of uneasy curiosity" (CW III, 307). As he considers the schoolmaster a "gigantic paradox," so, too he consigns to his mysterious double his own "intolerable spirit of contradiction" (CW III, 306). Flawed conscience figure and a barrier to moral awareness, his double mirrors his unresolved internal division. He devises a convoluted defense strategy, not fully realizing the extent to which he is his own worst enemy.

As in “Ligeia” and “The Fall of the House of Usher,” Poe’s “William Wilson” explores architectural imagery that symbolically gives expression to the involuted workings of the mind of individuals who show symptoms of facial recognition psychopathy. Poe conveys in psychologically symbolic imagery the ambivalent responses of the protagonist to the temporal and spatial restrictions of his boyhood world: “At an angle of the ponderous wall frowned a more ponderous gate. It was riveted and studded with iron bolts, and surmounted with jagged iron spikes. What impressions of deep awe did it inspire! It was never opened save for the three periodical egressions and ingressions. in every creak of its mighty hinges, we found a plenitude of mystery—a world of matter for solemn remark, or for more solemn meditation” (CW III, 302). A seemingly superfluous vignette, his description of the Elizabethan house juxtaposes imprisonment and metaphysical power. Seamlessly, he segues from the “place of enchantment” to the convoluted mental contortions he suffered: “There was really no end to its windings—to its incomprehensible subdivisions. It was difficult, at any given time, to say with certainty upon which of its two stories one happened to be. From each room to every other there were sure to be found three or four steps either in ascent or descent. Then the lateral branches were innumerable—incomprehensible—inconceivable—and so returning in upon themselves, that our most exact ideas in regard to the whole mansion were not very far different from those with which we pondered upon infinity” (CW III, 303). His mind meanders, ascending or descending from one level of meaning to another.

Completing its movement inward, his description concludes with the schoolroom. His objective recall of particulars is colored by his childhood impressions. His cryptographically clear yet indecipherable close-up view is reflective of his perceptual blindness: “The school-room was the largest in the house—I could not help thinking, in the world. It was very long, narrow, and dismally low, with pointed Gothic windows and a ceiling of oak. Interspersed about the room, crossing, and recrossing in endless irregularity, were innumerable benches and desks. so be seamed with initial letters, names at full length, grotesque figures, and other multiplied efforts of the knife, as to have entirely lost what little of original form might have been their portion in days long-departed” (CW III, 303–4). Hyperaware of the spatial and temporal limits of the school and its routine, he, “by a mental sorcery long forgotten," transforms his sense of containment, oppression, and restriction, creating "a wilderness of sensation, a world of rich incident, a universe of varied emotion, of excitement the most passionate and spirit-stirring" (CW III, 304). He is a transcendentalist manqué because his perception of his restricted lifestyle hermetically encloses him in a state of isolation from reality.

Unable to admit his mental distress is linked to excessive regimentation, he gives free rein to his tendency to worship his oppressive pastor and to revel in hysteria. He is as mentally disturbed as he tells his story as he was when he felt claustrophobic as a schoolboy. His diseased mind has worsened in that the intimidating schoolmaster's image is so deeply imprinted in his psyche that he has internalized the schoolmaster, which enables him to project the moral sense, attributing to his double the moral presence of the pastor.

Because he is unable to remember the pastor's face, a symptom of his facial recognition psychopathy, he is likewise unable to discern the facial features of his double. His partial recognition of his similarity to his stalker adds to his deprecation. He acknowledges his double's moral superiority but continues to deprecate the second Wilson. He notes that the very likeness forms a basis for his feeling of antagonism; yet, his apparent self-alienation is linked to vague childhood memories of his father. He confesses, "I had always felt aversion to my uncourtly patronymic. and when. a second William Wilson came also to the academy, I felt angry with him for bearing the name, and doubly disguised with the name because a stranger bore it, who would be the cause of its twofold repetition, who would be constantly in my presence. The feeling of vexation thus engendered grew stronger with every circumstance tending to show resemblance, moral or physical, between my rival and myself" (CW III, 308). While he resents the resemblances, he is nonetheless fascinated by his double's sense of drama: "His cue, which was to perfect an imitation of myself, lay both in the words and in actions; and most admirably did he play his part. My dress it was an easy matter to copy; my gait and general manner were, without difficulty, appropriated. even my voice did not escape him. My louder tones were, of course, unattempted, but then the key, it was identical; and his singular whisper, it grew the very echo of my own (CW III, 308). He shuns the idea of a "resemblance, moral or physical," but he criticizes his double for presuming "to refuse implicit belief in my assertions, and submission to my will—indeed, to interfere with my arbitrary dictation in any respect whatsoever" (CW III, 305). Nevertheless, he concedes his twin's moral worth: "Yet, at this distant day, let me do him the simple justice to acknowledge that his moral sense was far keener than my own; and that I might, today, have been a better, and thus a happier man, had less frequently rejected the counsels embodied in those meaningful whispers which I then but too cordially hated and too bitterly despised" (CW III, 310). His recognition of his double's moral stature is consistent with his show of remorse at the beginning of his story. Indeed, he attempts to designate in terms of time "at this distant day," "I might, today, have been" and "whispers which I then. hated") that he has acquired moral sense.

In a progressive unmasking of conscience, he describes many encounters with his double, whose purpose, moral restraint, he failed to recognize. Gradually, we begin to suspect that his encounters with his double are full-blown symptoms of facial recognition psychopathy. Each of his encounters with his putative stalker occurs in a different social setting, which suggests that he projects his repressed image of himself as conscience figure outward to the point where his self-image obliterates and displaces the faces of persons whom he encounters as he makes his way from one gambling house to another.

This trajectory traces two paths, his actual visits, during which he feels increasingly persecuted by persons whose gaze he misinterprets as projections of his double, but, in reality, he projects his self-image as a morally aware dissipated gambler on individuals in his social surroundings who, he imagines, are looking askance at him as he fritters away his fortune. In other words, his allegations get stronger, indicating that, unwillingly, persons in his social circle are making him feel guilty about his misconduct as a man who is addicted to gambling.

Each meeting with his double happens when his imagination is awake but his mind is half asleep or stimulated by wine. Each confrontation results in a simultaneous victory and defeat for his double, who conveys his disapproval of his improprieties and deceptions; however, his reception of the moral warning results in an increment in his wickedness. The more he sees, the more he feels compelled artfully to disguise what he sees. Motivated by self-defeating desire to assert his will, he enshrouds his glimpses of moral truth in melodrama. Glorifying his vice to justify his wayward behavior, he veils his encounters with "CONSCIENCE grim, /That specter in my path" (CW III, 299) in little melodramas in which he plays the role of surprised victim. But he gets ensnared by his ruses. It is Poe who makes light proceed from darkness.

At the heart of the tale, the wily monologist recalls how he once gazed at his sleeping double's face in the harsh glare of a lamp and sneaked away amazed and incredulous: "The bright rays fell vividly upon the sleeper, and my eyes, at the same moment, upon his countenance. I looked;—and a numbness, an iciness of feeling instantly pervaded my frame. Were these—these the lineaments of William Wilson?" (CW III, 312). "Awestricken" by the resemblance, he fled "at once, the halls of that old academy, never to enter them again." Immediately thereafter, he plunged into a "vortex of thoughtless folly" and "miserable profligacy" at Eton. After "three years of folly," resulting in "rooted habits of vice," he is interrupted one evening while "insisting upon a toast of more than wonted profanity" (CW III, 314). A sophisticated rake, he finds that he is forced by willful determination to cling to a raft of feigned ignorance, to frame his conscience in a protective curtain of shadows: "In this low and small room there hung no lamp; and now no light at all was admitted, save that of the exceedingly feeble dawn which made its way through the semi-circular window. As I put my foot over the threshold, I became aware of the figure of a youth about my own height, and habited in a white kerseymere morning frock, cut in the novel fashion of the one I myself wore at the moment. This the faint light enabled me to perceive; but the features of his face I could not distinguish (CW III, 314, my italics). Readers who are knowledgeable about facial recognition psychopathy may readily identify the narrator, who only seems to suffer from a form of paranoia, a persecution complex, as afflicted, evidently from childhood, with a debilitating facial recognition impairment that prevents him from enjoying normal social relationships.

Aware his discomfiture in social situations lies in his own personality, he sought help from a classmate, but when he approached, his misery blocked his eyesight. A projected image energized by his conscience is a sign of his moral aim to connect with his fellow student, but this image also prevents him from recognizing the face of a member of his peer group.

Nevertheless, he partially comprehends the significance of this incident. Without knowing the medical terminology, he understands enough to realize he has a disability. He does not want to forget the incident that made him realize he is deficient in his ability to recognize faces. Unfortunately, his memory plays tricks on him, and he starts to see his projected image of a facet of his personality, i.e., his moral sense, in the form of spectral conscience figures emanating from the depths of his being, his soul. Without the benefit of medical diagnosis and treatment, he obtains relief in venting his frustration and emotional overload in telling his story. In writing "William Wilson," Poe anticipates the therapeutic method advocated by Freud, a physician who devoted his medical practice to providing palliative care to patients who suffered from acute mental disturbances. He, like his colleagues in the medical profession, prescribed drugs to alleviate pain and suffering, but the contribution to medical science for which he was feted by his peers and acknowledged by intellectuals, as the father of the psychoanalytical school of thought, was his emphasis on interpretation of dreams (symbology) and free association (liberating the subconscious mind through spontaneously generated word linkages).

The lamplit face imagery reappears at key moments in the narrative, confirming William Wilson's facial recognition psychopathy, in the form of the second Wilson, whose presence coincides with inner promptings normally associated with twinges of conscience. Since he lacks the benefit of a medical diagnosis, he is reduced to taking evasive action. Not surprisingly, he develops a sociopathic antipathy to society. His double is a ghostly silhouette whispering in his ear: "It was the pregnancy of solemn admonition in the singular, low, hissing utterance; and, above all, it was the character, the tone, the key, of those few, simple, and familiar, yet whispered syllables, which came with a thousand thronging memories of by-gone days" (CW III, 314). Interpreting the utterances as the "insinuated counsel" (CW III 315) of his double, he is not detained by a serious consideration of the implied reproof: "Although this event failed not of a vivid effect upon my disordered imagination, yet was it evanescent as vivid. But in a brief period, I ceased to think upon the subject; my attention being all absorbed in a contemplated departure for Oxford" (CW III, 315). Suggesting that his double aroused no change in him, he reports that his "constitutional temperament broke forth with redoubled ardor" on receipt of a large endowment from his parents: "I spurned even the common restraints of decency in the mad infatuation of my revels" (CW III, 315).

For two years, he, carefree, dashing gambler, increases his "already enormous income at the expense of the weak-minded" (CW III, 316). Upon unintentionally causing the financial ruin of a gentleman named Glendinning, reputedly an "immeasurably wealthy" nobleman (CW III, 318), he is exposed as a cheat. Having maintained the appearance of a debonair gambler, he is disturbed by the reproving looks of those who pity Glendinning for falling prey to being victimized: "The pitiable condition of my dupe had thrown an air of embarrassed gloom over all. I could not help but feel the many burning glances of scorn or reproach cast upon me by the less abandoned of the party. I will even own that an intolerable weight of anxiety was for a brief instant lifted from my bosom by the sudden and extraordinary interruption which ensued" (CW III, 318). Transforming guilt into wonder, he embarks on another flight of fancy. A whispering voice exposes him; it is, at least in spirit, an oblique confession: "The wide, heavy folding doors of the apartment were all at once thrown open, to their full extent, with a vigorous and rushing impetuosity that extinguished, as if by magic, every candle in the room. Their light, in dying, enabled us just to perceive that a stranger had entered, about my own height, closely muffled in a cloak. The darkness, however, was now total; and we could only feel that he was standing in our midst. 'Gentlemen,' he said, in a low, distinct, and never-to-be-forgotten whisper which thrilled me to the very marrow of my bones. 'You are, beyond doubt, uninformed of the true character of the person who has to-night won at *écarté.* Please to examine the inner linings of the cuff of his left sleeve'" (CW III, 318–319). Distracted by the auditory impression made by the words, the morally blind narrator fails to apprehend the sense. Bridging the gap between the rapidly fading appearance of mere mischief and the emergent reality of his deceit, his double, carrying out the joyless task of "fulfilling a duty" (CW III, 319) informs the company of the fraudulent deception. Already aware that Glendinning was victimized by Wilson, the room remains silent: "Any burst of indignation upon this discovery would have affected me less than the silent contempt, or the sarcastic composure, with which it was received" (CW III, 320). His mask of respectability worn thin, he is less concerned over his humiliating exposure as a card shark than he is appalled and offended by the stranger's temerity in thwarting him from reaching his goal.

Accustomed to the servile obsequiousness usually bestowed on him by sycophants, he boorishly denounces the stranger: "In no one of the multiplied instances in which he had of late crossed my path, had he so crossed it except to frustrate those schemes, or to disturb those actions, which, if fully carried out, might have resulted in bitter mischief. Poor justification this, in truth, for an authority so imperiously assumed!" (CW III, 322). His growing awareness of his double as a conscience figure increases but, so, too, is his persecution complex sharpened. Ironically, when he scornfully belittles his double's cloak-and-dagger approach, he unintentionally mocks himself: "I had also been forced to notice that my tormentor, for a very long period of time, had so contrived it, in the execution of his varied interference with my will, that *I saw not, at any moment, the features of his face* [my italics]. Be Wilson what he might, *this* [italics in text], at least, was but the verist of affectation, or of folly" (CW III, 322).

Overarching self-pride causes him to brandish his facial recognition psychopathy as a weapon in that he attributes his duplicity and entrapment tactics against Glendinning to the stranger who exposes his swindle: "Could he, for an instant, have supposed that, in my admonisher at Eton—in the destroyer of my honor at Oxford—in him who thwarted my ambition at Rome, my revenge at Paris, my passionate love at Naples, or what he falsely termed my avarice in Egypt,—that in this, my arch-enemy and evil genius, I could fail to recognize the Wilson of my schoolboy days? Impossible!" (CW III, 322). He credits his double with his own failures. His references to his "honor," "ambition," "revenge," "passionate love," and "avarice" are melodramatic and ironically reflect his lack of honor, insincerity, excesses, and lack of self-knowledge.

As the widower in "Ligeia" claims that his first wife possesses supernatural powers, hence is not a bona fide person, so, too, the hard-drinking gambler, who is caught in the act of cheating, alleges that he is foiled not by a member of human society, but a mysterious phantom who wields a cosmic force beyond his control: "The sentiment of deep awe with which I habitually regarded the elevated character, the majestic wisdom, the apparent omnipresence and omnipotence of Wilson, added to a feeling of even terror with which certain other traits in his nature and assumptions inspired me, had operated, hitherto, to impress me with an idea of my own utter weakness and helplessness, and to suggest an implicit, although bitterly reluctant submission to his arbitrary will" (CW III, 322–23). Consistent with his heightened dissipation, he distances himself from his double; and thus, he consciously lays claim to willfully committing fraud against Glendinning and the moral standards of society.

The setting of the final confrontation is a masquerade ball. Intoxicated, belligerent, and confused, Wilson is held back while "anxiously seeking (let me not say with what unworthy motive) the young, the gay, the beautiful wife of the aged and doting DiBroglio" (CW III, 323). Wilson claims that he heard his double's "ever-remembered, low, damnable whisper" and, he says, "I turned at once upon him who had thus interrupted me" (CW III, 323–24). Having anticipated interference from his double, he immediately affronts a man who, like himself, wears "a mask of black silk [that] entirely covered his face" (CW III, 324). His accusations are ironic reflections of his own dishonorable intentions: "'Scoundrel!' I said, in a voice husky with rage, while every syllable I uttered seemed as new fuel to my fury, 'scoundrel! Accursed villain! You shall not—you *shall not* dog me unto death!'" (CW III, 324). He presents the dramatic closet scene as the final battle with his double, but there are also subtle signs of unacknowledged foul play.

In my critical opinion, scholars, and critics have overlooked subtextual insinuations that the monologist has murdered not his projected image of moral conscience but an actual person in his story, most likely the "aged and doting" Duke DiBroglio. In describing the old-fashioned Renaissance cloak and dagger duel, he ascribes great strength to himself, while his perceived rival, hitherto presented as aggressor and villain, now appears weak and frail: “He staggered against the wall, while I closed the door with an oath, and commanded him to draw. He hesitated but for an instant; then, with a slight sigh, drew in silence and put himself upon his defense” (CW III, 324). He presents himself as a glorious victor: “The contest was brief indeed. I was frantic within every species of wild excitement, and felt within my single arm the energy and power of a multitude. In a few seconds I forced him by the sheer strength against the wainscoting, and thus, getting him at mercy, plunged my sword, with brute ferocity, repeatedly through and through his bosom” (CW III, 324). He places the brutal murder in the context of a melodrama, with himself emerging as a romantic hero. Finding refuge in confusion, the evil gambler, anxious to impart the belief that he killed a mysterious stranger whom he would mistake for himself, approaches the truth:

“A large mirror, so at first it seemed to me in my confusion—now stood where none had been perceptible before; and, as I stepped up to it in extremity of terror, mine own image, but with features all pale and dabbled in blood, advanced to meet me with a feeble and tottering gait. Thus, it appeared, I say, but was not. It was my antagonist—it was Wilson, who then stood before me in the agonies of his dissolution. Not a thread in all his raiment—not a line in all the marked and singular lineaments of his face which was not, even in the most absolute identity, mine own!” (CW III, 325). His claim that he has slain an imaginary conscience figure, a self-projected image, depends on his identification of the decedent as Wilson.

But I contend that his facial recognition psychopathy prevents him from serving as a reliable narrator. His neurological impairment blocks him from recognizing the identity of the nobleman who whispered admonishing warnings to him when he was winning at cards by cheating. In contradistinction to David Ketterer, who interprets the slaying of the double by Wilson as “the suicidal conclusion of ‘William Wilson’” (184), William Howarth asserts that “The double is Wilson’s diseased Self, or at least a manifestation of that Self. Destroying the double is his ultimate act of selfishness, yet paradoxically, that deed effects his cure” (21). As Howarth suggests, when Wilson destroys his double, a psychological aberration, he seems to succeed in reintegrating the alienated conscience inasmuch as the conventional moral sense implied in the word “ought” is internalized. But this means that he now knows that he is guilty, not innocent. The act that renders him more conscious of the moral significance of his actions is an act of murder, according to Howarth, a symbolic act, but in my view, a criminally insane act. Wilson counteracts the gain in personality integration by at the cost of a corresponding increase in immorality. His life of "unpardonable crime" has brought him happiness, but "unspeakable misery" (III, 299). To compound matters, he seems to think that he now lacks a conscience, but his tortuous monologue suggests otherwise. Ultimately, his failure lies in the direction of his lack of full consciousness, caused by his facial recognition psychopathy.

4.9 FROM REPRESENTATION OF REALITY TO ROBOTIC RECOGNITION HELPERS

Ligeia's husband is oblivious of the way his hidden motives affect his selection, manipulation, and perception of material objects, among which are the décor of an abbey he purchases and the architectural features of a nuptial chamber; indeed, to his flawed perception, a wife is a material object he owns. Although he describes Ligeia in minute detail, he nevertheless fails to recognize the role she plays in revealing his psychic and moral nature. Virtually ignoring Ligeia as the woman she is, she appears to his mind's eye as a paragon of perfection. Her character is conceived and molded in his mind, like a fictional character. As described by the narrator, she is a mentally fashioned image of his ideal woman. Literary critics observe that Ligeia is partly a serious representation and partly a satirical treatment of the dark romantic lady of gothic romance (Griffith, Gargano, Stovall). As the author, Poe embeds the unconscious motives of the narrator, Ligeia's husband, in the subtext. Poe confers on the narrator the freedom to express conscious desires which, however, emanate from motives of which he remains unaware. Poe weaves the narrator's impaired facial recognition into the story such that this psychological flaw becomes readily apparent to readers who decipher the meaning of the story by analyzing metaphors, imagery, and symbolism contained in the narrator's self-dramatizing narrative discourse.

Reversing and undermining qualities of traditional romantic heroines, Poe's tale of mystery and imagination conveys moral and artistic purpose. Unbeknownst to the narrator, his soul is the site of a conflict between two dynamic forces that gradually become polarized as good and evil. These polar opposites change places in a subtle and ironic reversal at the end of the narrative. Throughout the tale, the narrator showcases his first wife, Ligeia, who outshines Rowena, his second wife; nevertheless, his innate tendency is toward Rowena. LL, a gorgeous brunette, represents the narrator's idealized knowledge of truth, beauty, and goodness. LR, the lovely blonde, actually represents material wealth, gold, or more precisely, the narrator's thirst for gold. The narrator downplays Rowena, reserving all his praise for the spiritually inclined, intellectual Ligeia. Ostensibly the dark woman associated with dark passions, Ligeia elicits not only the narrator's feelings of romantic love; he also stands in awe of her "stern passion" (Poe, *Complete Works* II, 249). The psychic transformations he undergoes, from ideality to materialism, from the material to a final insight that coincides with his attainment of complete bliss, commingled with woe—these internalized events are given objective expression in melodramatic scenes of Ligeia's death and revivification. Poe's depiction of the narrator's failure to attend to Rowena and frenzied struggle to resuscitate Ligeia points to the psychic mechanism that enables a serial murderer to break the law repeatedly without compunction. David Halliburton describes this soporific emotional turgidity: "If Ligeia's soul-mate shrieks when she returns, it is because that return in one sense confirms his inferiority—makes him, in a word, a victim. This transcendent woman possesses all life and all power; takes up all the breathing space; reduces the man to a position of despair, or adoration. He could never, if he wanted to, be rid of her. But does he want to be? For this defeat is also a kind of triumph. To experience the return of the other, to watch her emerge victorious, is to experience vicariously the reality of transcendence. Woman has proved, through the force of her will, that life is everlasting. The achieving of this complex goal, the victory which is also a defeat, is at once a tribute to the continuity of personal identity and a bridge to eternal salvation" (Halliburton 218). But as I have shown, the narrator suffers from facial recognition psychopathy, which results in the sort of sociopathic transcendence of one's fellow human beings that is associated with criminality, yet is symptomatic of latent moral awareness.

Similarities link "Ligeia" to "William Wilson," but the structural design of the latter is a key that unlocks the locked room mystery of the two women conscience figures in the former.

Poe, in "William Wilson," constructs the narrative in a way that foreshadows the cosmological scheme he presents in *Eureka: A Prose Poem*, which was published posthumously in 1851 with the subtitle "*An Essay on the Material and Spiritual Universe*." In *Eureka*, Poe endeavors to conceive of matter in its simplest form and envisions "a particle of one kind—of one character—of one nature. a particle absolutely unique, individual" (Poe, *Complete Works* XVI, 207). This atomic unit may be split "because He who created it, by dint of his Will" can divide it through the "energetic exercise of the same Will" (CW XVI, 207). The purpose of the creation of this article is the "constitution of the Universe from it" (XVI, 207). Through the action of diffusion, a visible, material universe emanates from the invisible "primordial Particle" (CW XVI, 207). By the double nature of this spiritual center, which is essentially an empty core, a void, a nothingness, the diverse and multiple material particles are made to form a unified design: "The design of variety out of unity—diversity out of sameness—heterogeneity out of homogeneity—complexity out of simplicity—in a word, the utmost possible multiplicity of relation out of the emphatically irrelative One" (CW XVI, 208). The first particle of matter corresponds to the "primordial Particle," in which reside the diametrical opposites of oneness and endless divisibility: "The assumption of absolute Unity in the primordial Particle includes that of infinite divisibility" (CW XVI, 207). Joseph Jean-Claude, who specializes in laser optics, psychophysics, and cognitive science, observes symmetry's "plurality of attributes": "From that vantage point, the state of symmetry immanent to a circle or a sphere (3D circle) is unitary, in the sense that every point on the circle is interchangeable with one other point in only one way, defined by the radius of the circle, whereas the point[s] on an ellipse have two ways to interchange with one another, as referentially defined by the major and the minor axes. Therefore, the state of symmetry immanent to an ellipse is twice as rich as the unitary state of symmetry attributable to the circle. There is to it a binary quality, in opposition to the unitary quality of the monolithic state of symmetry of a circle or a sphere" (17).

In his tales of mystery and imagination, Poe selects a first-person narrator and endows this primary narrative unit with "one nature," making it "a particle absolutely unique, individual." William Wilson is also a narrative unit that is divided against itself. He has a double nature, partly creative, partly destructive, in my view, comparable to the fusion of a photon and graviton. Poe's narratological strategy may be analogized such that the moral element is comparable to an electron in its elliptical orbit about a proton (personality). It is plausible that Poe's depiction of fictive subjects displaying symptoms of facial recognition psychopathy may serve as blueprints helpful to workers in AI capable of devising robotic or computerized helpers. Certainly, Poe's "William Wilson" and *Eureka* are most compatible with, and anticipatory of, contemporary scientific research. In the observable electromagnetic realm of elementary subatomic particles, according to André Michaud, a specialist in quantum mechanics and neurolinguistics, who in a Research Gate discussion with the author about submicroscopic, macroscopic, and astronomical particle physics, uses "a metaphor to highlight that within the hydrogen atom, the electron is as far from the proton as Neptune is from the Sun, if we were to increase the measured volume of the proton to the same volume as the Sun" (Michaud, 2019), such that "if the proton of a hydrogen atom (two of which are part of a water molecule) was enlarged to become as big as the Sun, the electron stabilized at mean distance from the proton into its least action orbital would then be as far away from this enlarged proton as the orbit of Neptune is from the Sun in the Solar system, meaning that the hydrogen atom would become as large as the entire Solar System" (Michaud, 2019).

As the narrator of the story, Wilson is born with his initial utterance and he dies with the final word in the narrative, which stops. His existence is identical with the words of his narration. As a first-person narrator, Wilson is made to articulate the words of the narration, thus he dramatically creates, or irradiates himself. However, there is a discrepancy between the image he thinks he is creating and the image he unwittingly creates. Therefore, not unity, but duplicity, or difference from unity resides at the core of his ontological being. Wilson is held within the dominion of his own will; however, his will is divided against itself. When his double finally appears to abdicate, the narrator informs the reader through the words of the alienated portion of his psyche, his conscience, that he has just narrated an act of metaphysical suicide. The suggestion that he has been secretly aware—though still imperfectly aware—of the nature of his offense against self and society implicates him in a less romantic, more serious wrongdoing than the one he describes in his melodramatic tale. His facial recognition psychopathy mitigates the criminality of his homicidal act. More importantly, in depicting two unreliable narrators in "Ligeia" and "William Wilson," Poe furnishes modern social scientists with credible examples worthy of study by health care workers, as well as friends, relatives, and family members of individuals who experience symptoms that may be traceable to facial recognition psychopathy. Robotic recognition helpers are needed as prompters to enable patients suffering from facial recognition psychopathy to identify persons in their social milieu. A robotic helper programmed like a telephone to act as a spokesperson, whenever the patient needs to interact with someone, can serve as a security guard to mitigate the effect of affective psychosis that triggers sociopathic projection of self-hostility. Poe's depictions of the husband in "Ligeia" and the gambler in "William Wilson" are representations of reality that demonstrate, in the simulated virtual reality of imaginative literary art, the need for a palliative, artificially intelligent robotic helper to compensate for the psychopathological blindness that prevents sufferers of facial recognition psychopathy from objectively and accurately identifying individuals in their social environment. Poe's fictional characters illustrate the mercurial traits of persons afflicted by facial recognition psychopathy, whose trajectory in their social circle is elliptical and oblique, and an essential aspect of their character remains hidden and turned away from society. A designer robotic helper will enable individuals who are handicapped by this neurological defect to be identified appropriately as disabled.

4.10 NEWTON, BOHR, EINSTEIN, AROUSAL, AND COVALENT BONDING

In psychology, the noun "affect" [af′ekt] means the experience of feeling an emotion or a mood and carries specialized meaning in psychopathology, in which "affect" refers primarily to the outward expression of emotions and moods. There are three dimensions of affect:

1. **Valence:** It refers to the intrinsic attractiveness or aversiveness of a situation, an object, or an event. The feelings of attraction or repulsion are shaped by an individual's principles, standards, and judgments; hence valence reflects a person's values
2. **Arousal:** It refers to the activation of an individual's nervous system, which may be appropriate or inappropriate. For instance, a person may experience agitation that is caused by an abnormal mental state, characterized by a desire to take action without knowing the reason why. This absence of cognitive awareness may be dangerous both to the person and other people in the social environment
3. **Motivational Intensity:** It refers to an impulsion to act and the strength of the urge to move toward or away from a stimulus, for example, a person's decision whether to interact with another person or not, or whether to get involved in a situation or not.

My application of quantum theory to cognitive affect in Poe's psychological tale "Ligeia" focuses on the ending, where the motivational intensity of the narrator, a remarried widower, toward his bed-ridden second wife, LR, attains equilibrium with his previous motivational intensity relative to his deceased first wife, LL. His multivalent emotional responses indicate that his behavior is dispersed and not well-focused. Instead of maintaining his integrity as a husband who loves his wives, first LL, and then LR, the narrator is physiologically aroused by two contradictory stimuli. In Newtonian terms, he is aroused by his physical proximity to Ligeia because he is attracted by her intelligence; however, at the same time, he is repulsed by his desire for her wealth and property. His motivational intensity is attenuated because divided between love for his wife and lust for her material possessions. Later, he is aroused by his physical proximity to LR, who, like her predecessor, LL, falls ill. He goes through the motions of administering a medicinal substance to her, but this potentially positive action is tainted by his manner. He is held in the grips of a subliminal urge to attain his objective to exchange his wedded wife for his wife's estate. His arousal level is divided between his need to maintain the appearance of helping LR to be cured of her illness and his overriding desire to gain possession of her estate.

Poe's portrayal of the love triangle is a literary version of quantum cognition that parallels quantum mechanics. The mystery tale "Ligeia" is an object modeled like astrophysical bodies in the mechanical universe of Isaac Newton (1643–1727); moreover, it withstands scrutiny under the subatomic microscopic theory of Albert Einstein. Einstein viewed his scientific achievements as carrying forward the work of Newton. On 7 November, 1919, the London Times headlines announced "Revolution in Science/New theory of the Universe/Newtonian ideas overthrown" (Pais, 47). While Einstein was affiliated with Hebrew University, he visited the tomb of Newton in December 1921. The most erudite of the French symbolist thinkers, Paul Valéry (1871–1945), recognized Poe as "a precursor of Einstein" because Poe observes that "every natural law has a reciprocal relation to all other laws" and "the very idea of matter is inextricably bound up with energy," which anticipates Einstein's representation of the universe ("la representation de l'univers Selon Einstein") (Watanabe, Beloved Image, 177). Valéry observes that in Einstein's cosmos, "Everything at a deeper level consists of agitations, rotations, exchanges, radiations. Our own eyes, our hands, our nerves, are made of such things" (Valéry, Collected Works, 8: 167). Poe knew the pathway from Newton to Einstein because he read Aristotle, Copernicus, Bacon, Galileo, Kepler, Descartes, Newton, Locke, Comte, Kant, Laplace, and others. Poe's tale "A Descent into the Maelstrom" (1841) centers on the force of gravity visual imagery of a vortex that forcefully ages a young man and transforms him into an old man, which coincides with Einstein's thought experiment in which a space traveler unburdened by gravity remains young while an Earthbound man who is weighed down by gravity ages.

Poe applies Newton's gravitation law pervasively in "Ligeia" and "William Wilson" and attains parity with Einstein's modification of $F = ma$, i.e., force equals mass times acceleration, as a narratological strategy. Just as Einstein discovered that $E = mc^2$, so Poe upgrades the mechanistic Aristotelian dichotomy of plot and character, as well as the Newtonian First

Law of inertial motion of the plot, character, and story. As Einstein discovered the photoelectric effect, so, too, Poe tunnels past Newton's macrocosm. The unreliable narrators in "Ligeia" and "William Wilson" can be viewed as personifications of a black hole, which exerts a gravitational pull that makes matter disappear into it. Ligeia's husband narrator omits any details about the death of LL. He simply asserts, "She died." And he inherits everything. Next, he weds LR and lives in a luxurious mansion. In agreement with the philosophical idea associated with Henri Bergson (1859–1941), that repetition affects the quality of experience, Poe differentiates the way the narrator experiences LL's death from the way he experiences LR's sickness. The reason he tells his story may be traced to his puzzlement over the difference between the way LL died and the way LR astounds him when he observes that her beautiful blonde hair transforms into Ligeia's raven black locks of hair. Bergson reasons that there is a difference between the presence of an object and its representation in the mind. The immediate perception of an object is different from the object because the representation is virtual because of image blends in one's consciousness with memories. The image of a material object "opposes to every action an equal and contrary action. and [is forced to] continue itself and to lose itself in something else" (Bergson, 28).

Poe's ambiguous, or open, endings anticipate the quantum theory interpretation proposed by Niels Bohr (1885–1962), who demonstrated the phenomenon of superposition. According to his Copenhagen interpretation of quantum theory, the location and the momentum of an object in a situation cannot be measured simultaneously. In 1935, Erwin Schrodinger discussed with Albert Einstein a thought experiment in which a cat is enclosed in a lead box that contains a radioactive trigger and a vial of poison. As long as the box remains closed, an observer cannot know if the cat is still alive or suffering ill effects from irradiated poison. Theoretically, quantum superposition may be applied to Poe's "Ligeia" and "William Wilson" because of the way they end. The narrators have a credibility gap, leaving readers uncertain as to whether William Wilson and LR are dead or alive. As the teller of a tale of conscience, William Wilson maybe a would-be moralist whose lesson is the biblical Golden Rule: "Do unto others as you would have them do unto you." It may be that the widowed husband has had his memory jogged so that he experiences an epiphany. In a moment of sudden insight, he recognizes that he wishes to kill LR for the same reason as he succeeded in slaying LL. Psychologically, his love for LR, to whom he is sexually attracted, causes his perception to be changed so as to enable his consciousness to gain cognitive equilibrium such that LR reaches effective situational entanglement with her husband's marital history. He looks at LR, whose image joins in a polar covalent bond with that of LL, whose death and gigantic intellect weigh heavily on his conscience at the other end of the spectrum from LR. Newton's Third Law is invoked as the narrator beholds LR and this action precipitates an equal and opposite reaction in his consciousness.

Poe portrays the narrator's differing affective responses to LL, whose intellect he respects, and to LR, whose physical beauty he admires. LL stimulates his desire to expand his mental faculties, his rational, emotional, and spiritual horizons. Unfortunately, this widening of his perceptual vistas contaminates his single-minded dedication to his role of husband, drawing his attention away from LL and undermining his efforts to be a happily married man. In other words, he grows less aware of his ontological existence as a man, and concomitantly, less aware of LL as a living being. This shift from existential awareness of himself as a body, i.e., a sensuous being, to abstract desire, i.e., obsessed preoccupation with acquiring wealth, altered his motivational intensity. Instead of viewing LL as the object of his love, he began to see her as an obstacle to his subconsciously plotted plan to obtain ownership of her possessions. In marked contrast, he is motivated by a carnal desire to possess the body and soul of LR. His physical attraction to his second wife conditions him to develop strong emotional responses to her physical being. Her outward appearance appeals to his sense of her womanly beauty, which arouses in him a longing to possess her as an epitomical paragon of wifely womanhood.

Whereas the intellectual and spiritual magnitude of LL inspires in her husband dark, otherworldly imaginings, the physical beauty of LR stabilizes his mind and emotions. His marriage to LR improves his cognition. His increased sense of masculine selfhood, including sexual attraction, cultivates in the narrator an ethical sense of responsibility that was lacking in his sublime and awe-inspiring relationship with LL. His married life with LL was one of transcendence beyond the confines of reality. Since he experienced no strong physical bonding with her, his lust for material profit easily outweighed the valence of his unworldly affection for her.

The ending of "Ligeia" anticipates the discovery of quantum entanglement, which is "one of the strangest phenomena predicted by quantum mechanics, the theory that underlies most of modern physics, which says that two particles can be so inextricably connected that the state of one particle can instantly influence the state of the other, no matter how far apart they are" ("Quantum entanglement," Internet). LL is deceased and she is located as far away from LR as the distance that separates life from death. Nonetheless, LL is entangled with LR.

"William Wilson" illustrates Newton's Second Law of Motion. William Wilson's double, named in the title "William Wilson," weighs the narrating gambler down, constantly bombarding him. In accordance with Newton's Second Law of Motion, the narrator only glimpses his conscience as a schoolboy, but then the time rate of change in the momentum of the gambler and the magnitude of his folly increase, relative to the psychic force his double exerts. William Wilson is, then, a molecule comprised of two atoms: the ghostly conscience figure resembles a photon that energizes whenever the dissipated gambler behaves unethically as his life descends into a whirlpool of crime. Gravitons and black holes in space have no mass The narrator claims that he fell into a black hole of evil suddenly and that his double pushed him. In the end, he disappears into the black hole like a graviton, with his double trailing behind, like an energized photon emitted when the narrator stabbed a man. "William Wilson" is a literary work of art that emulates covalent bonding in which William Wilson is intensely motivated to commit metaphysical suicide. Thus, as he loses his integrity, he intentionally shapes in himself into an archetypal dehumanized Nobody. Poe portrays a polar covalent bond in which William Wilson as an Anti-Christ who is located at the opposite pole from Jesus, the Son of God and filled with the Holy Spirit. "Quantum entanglement is one of the central principles of quantum physics. Quantum entanglement means that multiple particles are linked together in a way such that the measurement of one particle's quantum state determines the possible quantum states of the other particles. This connection is not dependent on the location of the particles in space. Even when entangled particles are separated by billions of miles, a change in one particle will induce a change in the other. Although quantum entanglement appears to transmit information instantaneously, it does not actually violate the classical speed of light because there is no 'movement' through space" (Jones, Internet). Jones observes that "the quantum state of every particle in the universe affects the wavefunction of every other particle, [but] it does so in a way that is only mathematical. There is really no sort of experiment which could ever—even in principle—discover the effect in one place showing up in another place" (Internet).

People in the social environment apply quantum theory to "affect" (noun) in Poe's psychological tale "Ligeia" to solve the hair color transform problem. At the end of the narrative, the motivational intensity of the narrator, a remarried widower, toward LR, and attains equilibrium with his motivational intensity toward LL. Covalent arousal bonding: negative LL + positive LR inhibits motivational intensity by stimuli: LR body consciousness via sexual attraction activates LL memory, and therefore, LR = LL.

Quantum entanglement is a physical phenomenon that occurs when a pair or group of particles is generated, interact, or share spatial proximity in a way such that the quantum state of each particle of the pair or group cannot be described independently of the state of the others, including when the particles are separated by a large distance. I interpolate the disparity between quantum entanglement as a primary feature of quantum mechanics that is lacking in classical mechanics. In contradistinction to critical interpretations of Poe's "Ligeia" as a supernatural tale that ends with the supposed revivification of LL, I propose that the ending is reflective of Poe's knowledge of scientific principles. Similarly, to Einstein, Poe was desirous of going beyond Newton's gravitational theory and laws of motion in the material universe. In "Ligeia," he applied his knowledge of Newton's scientific research, taking it to the next level, but in the domain of imaginative literature. Poe's portrayal of LR's blond hair changing into the black hair of his deceased first wife, LL, may be interpreted as a foreshadowing of Niels Bohr's discovery of quantum entanglement. Bohr discovered that any given pair of electrons behave randomly until an observer focuses on one of the two electrons, which puts the observed electron in a fixed state, thus allowing the second electron to be observed as behaving in a manner that is opposite to the first electron. Bohr here applies to the atomic and subatomic realm of quantum mechanics the same principle as holds true for Newton's Third Law of Motion, which governs the domain of such large-scale bodies as planets in our solar system. Newton's Third Law of Motion states that for every action there is an equal and opposite reaction ("Lex III: Actioni contrariam semper et æqualem esse reactionem: sive corporum duorum actiones in se muto semper esse æquales et in partes contrarias dirigi" (Philosophiæ Naturalis Mathematica Principia, 55)/"Law III: To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts" (The Principia, 439).

In Poe's "Ligeia," the relationship of the narrator to LL is based on his admiration of her intellectual ability, not her physical attributes. He succeeds in carrying out his plan to commit uxoricide because he is not physically attracted to her, even though she is sexually attracted to him. When he makes bodily contact with her, he presses his body against her, just as she presses her body to him. But he is motivated by murderous intent, while she is motivated by an equal and opposite desire for love-making. It is thus easy for him to kill his wife because she welcomes his embrace, which is motivated by an equal and opposite lust, not for her body, but, instead, for his material gains he will inherit from her estate after she is dead.

In striking contrast, the relationship of the narrator to LR is based on his attraction to her physical beauty; indeed, he is sexually attracted to her. Unlike the scholarly LL, who appeals to his intellect, LR calls his attention to his epistemological identity as a man in the sense of a physical body, to herself as a sensuous being, a sensual woman, and his lawfully wedded wife. Whereas he was distracted away from LL's presence as a physical being by his need to share his spouse's intellectual and spiritual pursuits, he is attracted to LR as a man is attracted to a woman as a member of the opposite sex. As LR's husband, he enjoys a normal physically intimate, mutually satisfying relationship with his wife. Her living presence becomes part of her estate. Although he is still motivated by a desire to possess her material wealth, she proves to become identified in his mind as synonymous with her possessions. He identified LL as an intellectual and spiritual being set apart from the material world. He was impelled to do away with her in order to acquire her wealth. But he learns to desire LR in the same way that he wants her money and property. His recognition of LR as an existential body, an object among other objects in the material world, enables him to measure her value in a substantial way. Subconsciously, he lusts after her body just like he covets her money and property.

Poe simulates entanglement in the realm of quantum mechanics by depicting entanglement in his putatively supernatural tale. Just as physical entanglement breaks through the barrier of Newton's classical mechanics, so, too, the theme of Romantic entanglement in Poe's "Ligeia" evokes quantum mechanics as applicable to imaginative literature. At the end of the story, the narrator achieves mental equilibrium when the electrifying intellectual passion of LL is entangled with the charged sexual passion of LR. Analogous to a pair of electrons located in different domains, LL in the heavenly domain to which her husband consigns her both in life and in death, LR in the empirically observable world of reality, the narrator's two wives symbolize an entangled pair of electrons. Poe's narrator in "Ligeia" may be viewed as a Romantic love physicist à la Niels Bohr. Quantum mechanics in physics defines entanglement such that measurement of one particle's quantum state determines the possible quantum states of the other particle. Poe's depiction of the husband of the entangled wives in "Ligeia" suggests that the supernatural tale is actually a fable, a tale of conscience in which the narrator acquires cognitive understanding of himself as a man, widower, and husband. In the end, he understands that there is no necessity for him to kill LR before he will gain possession of her estate.

KEYWORDS

- **Alzheimer's**
- **cognition**
- **conscience**
- **disability**
- **palliate**
- **psychopathy**
- **robotic helper**

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CHAPTER 5

AI PREDICTIVE DIGITAL ANALYTICS: A MODEL COMPUTING BASIS

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ABSTRACT

This paper presents novel model computing techniques with model diagrams for the tableaux with the applications to predictive modeling, forecasting, planning, and predictive analytics support systems. Newer surface vs. deep digitization analytics is previewed. A novel sequent visual tableaux analytics computation system with a specific mathematical basis is developed. Applications for designing forecasting analytics are examined. Morph Gentzen logic from the authors' publications since 1997 is the basis applied to forecasting analytics. Surface vs. deep digitization predictive analytics is presented with specific mathematical AI analytics techniques including nonmonotonic predictive model diagrams. Newer mathematical foundations are developed for the computing science that can forward visual agent computing predictive analytics, with applications to interactive predictive analytics. This includes Beth Tableaux's descriptive characterizations the author developed around 2000, for Morph Gentzen sequent, to obtain Morph Gentzen model-theoretic sequent compactness to realize Tableau models. Applications to explaining interactive visual analytics are presented with specific examples from the enterprise modeling industry. Data filtering with keyed functions are novel techniques for a visual surface to deep digitization, while rapid content processing and content delivery are alternate surface digitization functionality realized. Newer examples from industry goals for the innovations areas, for example, interactive analytics or digitization for rapid business automation or enterprise cloud or web interface processing are examined. A primary distinctive feature for what is presented in this

paper is that the predictive analytics are, for the most part independent from the historical data threads.

5.1 INTRODUCTION

Computing based on Intelligent Forecasting and Model discovery was studied by the first author since (Nourani, 1999). Multiagent business objects and Intelligent Multimedia applications for Management Science and IT were defined. Amongst the areas treated were agent computing, modern portfolios, heterogeneous computing, business objects, intelligent databases, intelligent objects, and decision science. Towards intelligent analytics interfaces, a novel sequent visual tableaux analytics computation system with a specific mathematical basis is developed. Applications to designing stock forecasting analytics are examined. Morph Gentzen logic from the first authors; 1977 basis is applied towards forecasting analytics. The presents novel model computing techniques with model diagrams for the tableaux with the applications to predictive modeling, forecasting, game tree planning, and predictive analytics support systems. Competitive model planning techniques have further applications to the new areas.

New applications to business with intelligent object languages were presented in brief. Intelligent multimedia and the new Morph Gentzen logic from (Nourani, 1997) are being applied as a basis for forecasting analytics. Here what applies is to present novel model computing techniques with model diagrams for the tableaux with the applications to predictive modeling, forecasting, game tree planning, and predictive analytics support systems. Generic diagrams are diagrams defined from a minimal set of function symbols that can inductively define a model. Generic diagrams are applied towards KR from planning with indeterminism and planning with free proof trees.

New sequent visual tableaux analytics computation system with a specific mathematical basis developed here. Applications to designing stock forecasting analytics that were presented since 1999 (Nournai, 1999) is outlined. A brief preliminary outline was announced at a virtual event at Slovakia (Nourani, 2015). The digital world is changing everything, AI and big data analytics are revolutionizing the way we make decision; billions of machines are connected through the Internet of Things (IoT) and interact on a whole new level and scale. The size of training datasets is often massive and continues to grow, with Facebook recently announcing it had compiled 3.5 billion public images. AI techniques such as artificial neural networks, genetic algorithms, case-based reasoning, methods from expert systems, and knowledge representation (KR) have been successfully incorporated into intelligent decision systems, intelligent agents (IA) have had the broadest applicability to decision problems.

Definitions of an intelligent agent vary, although the one given by Woolridge is often cited: “An agent is a computer system that is situated in some environment and that is capable of autonomous action in this environment in order to meet its design objective.” To this definition, additional capabilities may be added, including reactivity, proactiveness, social ability, adaptiveness, cooperation, persistence, and mobility. The chapter presents novel nonmonotonic model computing and Knowledge digitization techniques with model diagrams with the applications to predictive modeling, forecasting, game tree planning, and predictive analytics support systems. Generic diagrams are diagrams defined from a minimal set of function symbols that can inductively define a model.

Generic diagrams are applied to KR to define initial models and a minimal efficient computable way to discover specific models from knowledge represented. Generic diagrams are applied towards KR from planning with indeterminism and planning with free proof trees to partial deduction unfolding technique, with predictive diagrams presented here. A completeness theorem is proved on predictive diagrams as a model-theoretic basis to explanations. The application to proof abstraction alludes. A brief overview of a reasoning grid with diagrams is presented. The section outlines are as follows: Section 5.2 previews models and agent languages for AI agent logic processing. Section 5.3 introduces modeling with agents for planning that instantiates agent for uncertainty computations. Prediction and model discovery techniques with plan goals are presented.

Section 5.3 presents a multiagent visual computing logic while presenting the applications to learning, distinguishing a deep vs. surface digitization process. Further examples are explored with Intel and SAP HANA examples. Section 5.4 presents heterogeneous models for enterprise content models for surface digitization examples forwarding to visual model discovery on intelligent visual databases with the TAIM example. Data filtering with keyed functions encoding knowledge to databases. Section 5.5 is on the technical arena agent augmented languages. Agents, models, and algebras for visual multiagent computing are previewed and considered for abstract intelligent syntax specified business objects and model refactoring applications. The Morph Gentzen deductive system is briefly presented with applications to a virtual tree for multiagent visual planning.

Sections 5.6 and 5.7 present a visual computing on a sequent analytic tableaux this author has developed for predictive analytics applications past several years. Incomplete model diagrams are applied for analytics applications. Newer compactness properties for Morph Gentzen sequent proved to apply to visual explanations for interactive or noninteractive visual predictive analytics processes, thereby providing a mathematical basis for predictive visual analytics. Section 5.7 presents competitive learning models with model diagrams for business model (BM) digitization applications. Digitization functions are applied for reaching to deep knowledge with BM digitization implications. Relevant world KR on incomplete and nondeterministic free Skolem model diagrams are applied for model predictions and discovery with proof abstractions on virtual trees. Section 5.8 previews on the competitive models and the digitization economies.

5.2 MODELS AND LANGUAGES

To prove Gödel's completeness theorem, an important technique is by constructing a model directly from the syntax of the given theory. The structure is obtained by putting terms that are provably equal into equivalence classes, then defining a free structure on the equivalence classes. The computing and reasoning enterprise requires more general techniques of model construction and extension since it has to accommodate dynamically changing world descriptions and theories. Our techniques for model building as applied to the problem of AI reasoning allows us to build and extend models through model diagrams. This requires us to focus attention on the notion of a generalized diagram. The minimal set of function symbols are those with which a model can be built inductively. We focus our attention on such models, since they are Initial (ADJ, 1973) and computable (e.g., Nourani, 1984) We apply the canonical models since there are useful categorical computing properties (ADJ, 1973; Nourani, 1996).

A technical example of algebraic models defined from syntax had appeared in defining initial algebras for equational theories of data types, e.g., developed on our projects since 1978 (ADJ, 1973). In such direction for computing models of equational theories of computing problems are presented by a pair (Σ,E), where Σ is a signature (of many sorts, for a sort set S) and E a set of Σ-equations. Let $T<\Sigma>$ be the free tree word algebra of signature Σ. The quotient of $T<\Sigma>$, the word algebra of signature Σ, with respect to the Σ-congruence relation generated by E, will be denoted by $T<\Sigma,E>$, or $T<P>$ for presentation P. $T<P>$ is the "initial" model of the presentation P. The Σ-congruence relation will be denoted by $\equiv P$. One representation of T(P) which is nice in practice consists of an algebra of the canonical representations of the congruence classes. This is a special case of generalized standard models defined here.

For agent computing structures this author presented newer mathematical linguistics structures (Nourani, 1996, 1997) with a set of function symbols in the language, referred to by Agent Function Set, is a set of function symbols modeled in the computing world by Agents. The objects, messages passing actions, and implementing agents are defined by syntactic constructs, with agents appearing as functions, expressed by an abstract language that is capable of specifying modules, agents, and their communications. We have to put this together with syntactic constructs that could run on the tree computing theories. Sentential logic is the standard formal language applied when defining basic models. The language is a set of sentence symbol closed by finite application of negation and conjunction to sentence symbols.

When quantifier logical symbols are added to the language, the language of first-order logic (FOL) can be defined. A Model for is a structure with a set A. There are structures defined for such that for each constant symbol in the language there corresponds a constant in A.

For each function symbol in the language, there is a function defined on A; and for each relation symbol in the language there is a relation defined on A. For the algebraic theories we are defining for intelligent tree computing in the forthcoming sections, the language is defined from signatures as in the logical language is the language of many-sorted equational logic. The signature defines the language by specifying the function symbols' rarities. The model is a structure defined on a many-sorted algebra consisting of S-indexed sets for S a set of sorts.

In the following gt1…tn denotes the formal string obtained by applying the operation symbol g in Σ to an n-tuple t of arity corresponding to the signature of g. Furthermore, gC denotes the function corresponding to the symbol g in the algebra C.

The CTA's are specific canonical models. In the sections above, we have shown how to define models with Generic diagrams. Initial models are models definable by Generic diagrams. Let us carry the initial models onto the planning foundations.

5.3 PLANS AND UNCERTAINTY PREDICTIVE MODELING PREVIEW

Modeling with agent planning is applied where uncertainty is relegated to agents, where competitive learning on game trees determines a confidence interval. The incomplete knowledge modeling is treated with KR on predictive model diagrams. Model discovery at KB's are with specific techniques defined for trees. Model diagrams allow us to model-theoretically characterize incomplete KR. To key into the incomplete knowledge base, we apply generalized predictive diagrams whereby specified diagram functions a search engine can select onto localized data fields. The predictive model diagrams (Nourani, 1995) could be minimally represented by the set of functions {f1., fn} that inductively define the model. Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. Diagrams are well-known concepts in mathematical logic and model theory. The diagram of a structure is the set of atomic and negated atomic sentences that are true in that structure.

5.3.1 PREDICTION AND DISCOVERY

Minimal prediction is an AI technique defined since the author's model-theoretic planning project. It is a cumulative nonmonotonic approximation attained with completing model diagrams on what might be true in a model or knowledge base. A predictive diagram for a theory T is a diagram D (M), where M is a model for T, and for any formula q in M, either the function f: q → {0,1} is defined, or there exists a formula p in D (M), such that T U {p} proves q; or that T proves q by minimal prediction. Prediction involves constructing hypotheses, where each hypothesis is a set of atomic literals; such that when some particular theory T is augmented with the hypothesis, it entails the set of goal literals G. The hypotheses must be a subset of a set of ground atomic predictable. The logical theory augmented with the hypothesis must be proved consistent with the model diagram. Prediction is minimal when the hypothesis sets are the minimal such sets. A generalized predictive diagram is a predictive diagram with D (M) defined from a minimal set of functions. The predictive diagram could be minimally represented by a set of functions {f1…, fn} that inductively define the model. The free trees we had defined by the notion of provability implied by the definition, could consist of some extra Skolem functions {g1…,gl} that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize partial deduction with free trees. Prediction involves constructing hypotheses, where each hypothesis is a set of atomic literals fi; such that when some particular theory T is augmented with fi, it entails the set of goal literals G, i.e., $T \cup fi$ logically implies G, written $fi \models G$ (Shoenfield, 1967). fi must be a subset of a set of ground atomic predictable A. Its addition we must ensure $T \cup fi$ is consistent. The set of all possible hypotheses is $f = \{fi\}$. Prediction is minimal when the fi are the minimal such sets.

5.3.2 GOALS AND PLANS

Practical systems are designed by modeling with information, rules, goals, strategies, and knowledge bases. Patterns, schemas, and viewpoints are the 'micros' to aggregate information onto the data and knowledge bases, where masses of data and their relationships and representations are stored, respectively. Forward chaining is a goal satisfaction technique where inference rules are activated by data patterns, to sequentially get to a goal by applying the inference rules. The current pertinent rules are available at an 'agenda' store. The rules carried out will modify the database. Backward chaining is an alternative based on opportunistic response to changing information. It starts with the goal and looks for available premises that might be satisfied to have gotten there. Goals are objects for which there is automatic goal generation of missing data at the goal by recursion backward chaining on the missing objects as sub-goals. Data unavailability implies a search for new goal discovery.

Goal-directed panning is carried out while planning with diagrams. That part of the plan that involves free Skolemized trees (e.g., Nourani, 1995, 2002. 2003) is carried along with the proof tree for a plan goal. If the free-proof tree is constructed, then the plan has an initial model in which the goals are satisfied. A basis to model discovery and prediction planning is presented in Nourani (2002) and is briefed here. The new AI agent computing business bases defined during the last several years can be applied to present precise decision strategies on multiplayer games with only perfect information between agent pairs. The game trees are applied to improve models. The computing model is based on a novel competitive learning with agent multiplayer game tree planning. Specific agents are assigned to transform the models to reach goal plans where goals are satisfied based on competitive game tree learning. The planning applications include OR-ERP and EM as goal satisfiability and micro-managing ERP with means-end analysis on EP. Minimal prediction is an AI technique defined since the author's model-theoretic planning project. It is a cumulative nonmonotonic approximation.

Schemas allow brief descriptions on object surface properties with which high level inference and reasoning with incomplete knowledge can be carried out applying facts and the defined relationships amongst objects.

A scheme might be Intelligent Forecasting {IS-A Stock Forecasting Technique} Portfolios Stock, bonds, corporate assets Member Management Science Techniques We consider models as Worlds at which the alleged theorems and truths are valid for the world. Models uphold to a deductive closure of the axioms modeled and some rules of inference, depending on the theory. By the definition of a diagram, they are a set of atomic and negated atomic sentences, and can thus be considered as a basis for a model, provided we can by algebraic extension, define the truth value of arbitrary formulas instantiated with arbitrary terms.

A theory for the world reasoned and model is based on axioms and deduction rules, for example, a FOL theory. The above scheme with the basic logical rules, can form a basic theory T to reason about a stock forecasting technique. To do predictive analysis, we add hypotheses, for example, the atomic literals based on the following: p1. Asset (Stocks) p2. Stock (x) => Asset (x) p3. S&P100 (x) => Stock (x) From the definitions a predictive diagram for a theory T is a diagram D[M], where M is a model for T, and for any formula q in M, either the function f: q → {0,1} is defined, or there exists a formula p in D[M], such that T U {p} proves q; or that T proves q by minimal prediction. The predictive diagram for T is constructed starting with p1 = True, p2(f) = true for f ranging over stock symbols, p3 is true for all x = f, where f is a stock symbols in S&P100.

To predict if the stock f is due to increase in value might be inferred with a predictive diagram that includes hypothesis p3 on the stock symbol and that the average value of S&P100 is due to increase. For example, a predicate p4 that stock symbol f1 is in Sector S1 and the sector S1 is due an increase. New hypothesis: p4. stock (f1) => S1(f) p5. S1(x) => 25% increase average value (x) Thus T U p5 $\models$ increase value (f), i.e., the stock symbol f is predicted to appreciate. Example forecasting theory T based on the above is as follows. Defaults D: possible hypotheses, that we accept as part of a forecast and observations ϕ which are to be reconciled. An observation g ϵ ϕ is reconcilable if there exists ground hypotheses g in D such that 1. T U d logically implies g , and 2. T U d is consistent. The author's publications (Nourani, 2003) have proved that a set of first-order observations ϕ is reconcilable with the model iff there exists a predictive diagram for the logical consequences to ϕ.

5.4 A VISUAL COMPUTING LOGIC

A problem-solving paradigm is presented in the Double Vision Computing paper (Nourani, 1995, 1999). Agents at each world compliment one with object co-object pairs: problem-solving is carried on boards by cooperating agents from the pairs. The IM Hybrid Multimedia Programming techniques have a computing logic is mathematical logic where a Gentzen or natural deduction (Prawitz, 2006) systems is defined by taking multimedia objects coded by diagram functions. By transforming hybrid picture's corresponding functions, a new hybrid picture is deduced. Multimedia objects are viewed as syntactic objects defined by functions, to which the deductive system is applied. The formal AI and mathematics appear in the first author's mathematical logic publications since 1997 and applied to business areas at (Nourani, 2004, 2005), for example. The intelligent syntax languages are applied with Morph Gentzen.

5.4.1 MODELS, LEARNING, AND IM

A computational logic for intelligent languages is presented in brief with a soundness and completeness theorem in Nourani (1995, 1999) from the author's 1994 and applied to intelligent business object computing. The process characterizes computation with abstract syntax trees without grammar specifics. As an example, suppose you are told there is an academic department with a faculty member that is Superman, and two faculty members who are Swedish speaking, and three who do not talk to anybody not in their expertise area. Without telling you anything else about what they do, abstract syntax properties to express that world can be defined. When the signature's specific agent functions are defined, it implies the signature has defined message paths for them. The computation is expressed by an abstract language that is capable of specifying modules, agents, and their communications.

The implementing agents, their corresponding objects, and their message-passing actions can also be presented by the two-level abstract syntax. The agents are represented by function names that appear on the free syntax trees of implementing trees. To reach the models that are computable, we have to get a grip on a minimal set of functions to define tractable models. Such selector functions are applied to create compound business objects. Learning casual relationships amongst visual stored data is another important area, which can benefit from our project. Most existing learning algorithms detect only correlations, but are unable to model causality and hence fail to predict the effect of external controls. Visualization and interactive discovery data mining is a process which involves automated data analysis and control decisions by an expert of the domain. For example, patterns in many large-scale business system databases might be discovered interactively by a human expert looking at the data, as it is done with medical data.

The paper is a basis for model discovery, computation, and KR on generalized diagrams. It presents the method of generalized diagrams, abbreviated by Generic diagram, from Nourani (1995, 1999) that were invented for AI planning and reasoning, formulating various notions of generalized and free diagrams. It shows that Generic diagrams from the basis for minimal efficient KR, henceforth abbreviated by KR, paradigms. We also show the applicability of the Generic diagram method for KR to partial deduction from Hoppe (1994), where the author defined predictive diagrams. Furthermore, a brief connection is made from Hoppe (1994) to KR for proof abstraction methods in AI (Mosetic-Holsbauer 1991; Nourani-Hoppe, 1994), in the present paper, to show the applicability of the methods we are presenting with free proof trees.

Many examples are drawn from theories of AI to planning for robots to show the applicability of the techniques and theories proposed. World model revision is one of the difficult aspects of the nonmonotonic reasoning systems. Our papers (Nourani, 1995, 1999) presented a solution to it by the generalized diagram formulation, where models are implicitly revised through dynamic changes to the diagrams from which the models are built. Thus, we show that KR by Generic diagrams simplifies the world revision problem. The formulation of default in Nourani (1995, 1999), as further applied to predictive reasoning in this paper is referring to model-theoretic consistency. The practical problem of incomplete information in AI reasoning systems requires model revision when new information is given about the system. The canonical model of the world is defined directly from the diagram. Generalized diagrams are used to build models with a minimal family of generalized Skolem functions. The minimal sets of function symbols are functions with which a model can be built inductively. The functions can correspond to objects defining shapes and depicting pictures. The process here is to apply canonical models since they are standard for our BMs and computable. We cannot formalize the real world. AI Worlds are relevant descriptions for problem solving in the real-world parts. The uses of machine learning (ML) important opportunities for business value today. McKinsey estimates that around 43% of financial processes can be automated using AI, and Gartner believes that by reducing the need for action and choices. There is vast potential if you combine the power of ML with sensors, IoT, and other technologies.

5.4.2 SURFACE VS. DEEP DIGITIZATION

One dimension to surface digitization is with respect to visual analytics with, for example, agent encodings with Morph Gentzen deductive processes that are applicable to visual analytics or interactive analytics with the SAS example briefed on the following section. A second important surface digitization is with regards to the three important business areas: business processes, automation, web interfaces, and IoT. We examine views to surface digitization. Figure 5.1 is a typical enterprise web interface that is the obvious track for surface digitization.

FIGURE 5.1 Example intelligent visual database digitized content processing.

Example views to implement AI for business: robotics and robust ML algorithms are paving the tracks for AI for business: The thrust on AI enterprise systems is on process automation that requires ML and pattern recognition, to enable automation in business processes. For ML, abbreviating ML, to be successful there must be high-quality data. This is usually found in existing business applications such as finance, logistics, and sales, but not often threaded. The data in these systems might have already been collected, cleansed, and stored over a long period of time, so there is plenty of data available to create scenarios for predictive models.

ML works best when the coupled decision processes are defined for decision that might have to made Thought the day, that can be knowledge completed. For example, what invoice is for what bank. ML is easiest to implement when the decision can be seamlessly automated as part of an existing business process, rather than requiring new processes or cultural changes.

Some examples of automatable processes:

- Extracting relevant payment or order data from unstructured invoices;
- Predicting when contracts based on usage will need to be renewed;
- Predicting and acting on stock-in-transition;
- Predictive supply chain automation based on inventories;
- Routing customer service requests to the most appropriate teams.

5.4.3 THE INTEL-SAP HANA SURFACE DIGITIZATION EXAMPLE

Recent advances in ML have dramatically improved the ability of computers to decipher and understand human speech, writing, and commands. New service chatbots can make it easier for customers to find information and do simple transactions via voice or chat interfaces. ML algorithms can scan large amounts of product and technical documentation and automatically create answers to frequently asked questions. Inside organizations, new enterprise digital assistants can assist you throughout your working day, especially in the context of core business processes such as procurement, HR, and budgeting. Instead of clicking around in a complex interface, you could tell the digital assistant, "I'd like to book a week's vacation next week" or ask, "what's the current actual vs. budget for my department?" In a work environment, digital assistants have access to a vast amount of context that can be used to simplify or even anticipate the exchanges.

ML is being used to identifying and alert when a decision is about to be made about unusual circumstances, that travel credits for the firm might have to be examined. However, such surface digitization have deep digitization layers that might have to be examined to accomplish-

SAP HANA processes for supply chain optimization or hyperscale cloud platforms and advanced real-time analytics, SAP provides solutions that cover a company's entire value chain and information chain. Intel partnering with SAP is focused on simplifying digital transformation while building intelligent enterprises for the emerging experience economy. Here we observe what we mean by Surface digitization, for example, a multiyear technology partnership focused on optimizing Intel's platforms, including Intel® Xeon™ Scalable processors and Intel® Optane™ DC persistent memory, for end-to-end enterprise software.

In an accompanying chapter on this volume, the business perspectives for digitization are examined. What is presented in the present chapter is the technical analytics processes that might influence the entire processes delineated on digitization for business-specific areas (Nourani-Sieber, 2020).

5.5 HETEROGENEOUS MODELS

This author since the 1990's has presented techniques for design by software agents and new concepts entitled abstract intelligent implementation of AI systems (AII). Objects, message passing actions, and implementing agents are defined by syntactic constructs, with agents appearing as functions. The techniques have been applied to design intelligent business objects in Nourani (1996).

AII techniques have been applied to Heterogeneous KB Design and implementation. The application areas include support for highly responsive planning. The applied fields are, for example, intelligent business systems, aerospace, AI for robots, and multimedia.

5.5.1 SURFACE DIGITIZATION EXAMPLE: ENTERPRISER CONTENT MANAGEMENT AND PROCESSING

The World Wide Web was originally built for human consumption, and although everything on it is machine-readable, this data is not machine Understandable. It is very hard to automate anything on the Web, and because of the volume of information the Web contains, it is not possible to manage it manually. The solution proposed here is to use metadata to describe the data contained on the Web. Metadata is "data about data" (for example, a library catalog is metadata, since it describes publications) or specifically in the context of this specification "data describing Web resources." The distinction between "data" and "metadata" is not an absolute. It is a distinction created primarily by a particular application, and many times the same resource will be interpreted in both ways simultaneously.

Resource description framework (RDF) is a foundation for processing metadata; it provides interoperability between applications that exchange machine-understandable information on the Web. RDF emphasizes facilities to enable automated processing of Web resources. RDF can be used in a variety of application areas; for example: in resource discovery to provide better search engine capabilities, in cataloging for describing the content and content relationships available at a particular Web site, page, or digital library, by intelligent software agents to facilitate knowledge sharing and to exchange, in content rating, in describing collections pages that represent a single logical "document," for describing intellectual property rights of Web pages, and for expressing the privacy preferences of a user as well as the privacy policies of a Web site RDF with digital signatures will be key to building the "web of trust" for electronic commerce, collaboration, and other Trust" for applications. applications.

5.5.2 VISUAL MODEL DISCOVERY

Model diagrams allow us to characterize incomplete KR. To key into the incomplete knowledge base, we apply generalized predictive diagrams whereby specified diagram functions a search engine can select onto localized data fields. The predictive model diagrams (Nourani, 1994, 2003) could be minimally represented by the set of functions {f1…, fn} that inductively define the model. Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. We have developed techniques that can be applied to planning with diagrams to implement discovery planning. Computing with diagram functions allows us to key to active visual databases with agents. The incomplete knowledge modelling is treated with KR on predictive model diagrams.

Model discovery at KB's are with specific techniques defined for trees. Model diagrams allow us to model-theoretically characterize incomplete KR. To key into the incomplete knowledge base, we apply generalized predictive diagrams whereby specified diagram functions a search engine can select onto localized data fields. The goal formula states what relevant data is sought. We propose methods that can be applied to planning (Nourani, 2001) with diagrams to implement discovery planning Computing with diagram functions allows us to key to active visual databases.

5.5.3 TAIM AND DISCOVERY COMPUTATION

The morphing Transformer Active Intelligent Database designs outline is presented in TAIM (Nourani, 2010). Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. We have presented planning techniques, which can be applied to implement discovery planning. In planning with generic diagrams that part of the plan that involves free Skolemized trees is carried along with the proof tree for a plan goal. The idea is that if the free proof tree is constructed, then the plan has a model in which the goals are satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed. Partial deductions in this approach correspond to proof trees that have free Skolemized trees in their representation. While doing proofs with free Skolemized trees we are facing proofs of the form p(g(.)) proves p(f(g(.)) and generalizations to p(f(x)) proves for all x, p(f(x)). Thus, the free proofs are in some sense an abstract counterpart of the SLD. Let us see what predictive diagrams do for knowledge discovery knowledge management (KM). Diagrams allow us to model-theoretically characterize incomplete KR.

To key into the incomplete knowledge base. Generalized predictive diagrams are defined, whereby specified diagram functions and search engine can select onto localized data fields. A Generalized Predictive Diagram, is a predictive diagram where D (M) is defined from a minimal set of functions. The predictive diagram could be minimally represented by a set of functions {f1,…,fn} that inductively define the model. The functions are keyed onto the inference and knowledge base to select via the areas keyed to, designated as Si's in Figure 5.1 and data is retrieved (e.g., Nourani 2005). Visual object views to active databases might be designed with the above.

5.5.4 DATA FILTERING ON KEYED FUNCTIONS

Let us see what predictive diagrams do for knowledge discovery KM. Diagrams allow us to model-theoretically characterize incomplete KR to incomplete knowledgebase. Figure 5.2 depicts selector functions Fi from an abstract view grid interfaced via an inference engine to a knowledge base and in turn onto a database.

Practical AI systems are designed by modelling AI with facts, rules, goals, strategies, knowledge bases. Patterns, schemas, AI frames and viewpoints are the micro to aggregate glimpses onto the database and knowledge bases were masses of data and their relationships-representations, respectively, are stored. Schemas and frames are what might be defined with objects, the object classes, the object class inheritances, user-defined inheritance relations, and specific restrictions on the object, class, or frame slot types and behaviors. From Nourani (1999) scheme might be IS-A Stock Forecasting Technique Portfolios Stock, bonds, corporate assets Member Management Science Techniques Schemas allow brief descriptions on object surface properties with which high level inference and reasoning with incomplete knowledge can be carried out applying facts and the defined relationships amongst objects. Relationships: Visual Objects have mutual agent visual message correspondence. Looking for patterns is a way some practical AI is a carried on with to recognize important features, situations, and applicable rules. From the proof's standpoint, patterns are analogies to features as being leaves on computing trees. IM's basis for forecasting is put forth at preliminary stages in this authors publications this decade. The predictive model diagram applications were model diagram a basis for intelligent forecasting (Nourani, 1992a, 2015, 2018). There are graphics sequent for predicting the quarter earnings from the second and third combined with a market condition graph.

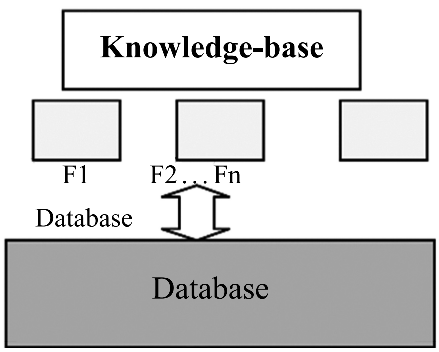

FIGURE 5.2 Keyed KB-database view.

Source: Adapted with permission from Nourani, 2019. © Apple Academic Press.

The way a market condition graph is designed is a propriety issue. It is obtained by Morph Gentzen sequent from known stock market parameters. Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. The basis for forecasting is put forth at preliminary stages in the author's publications since 1998. The idea is to apply Morph-Gentzen logic as a basis for intelligent multimedia forecasting. The figure indicates a graphics sequent for predicting the fourth-quarter earnings from the second and third combined with a market condition graph. The way a market condition graph is designed is a propriety issue.

5.5.5 SPARSE SPANNING BIG DATA

Agent state vectors are spanning with models for diagram values that either, true, false, or X-undermined. The cross product with the model diagram for vectors is a matrix. That matrix is sparse coding to bigdata with the X sparing the matrix, thus minimizing reaches for bigdata: hence sparse heuristics are entailed. Our newer techniques apply to the emerged a debate about the relative importance of ever bigger data versus ever better predictive techniques to avoid bigger data.

Not enough people have the necessary skills to make rigorous use of data. We start with outlining a sparse spanning-tree minimizing big data threading (e.g., Nourani, 2017; Nourani-Fähndrich, 2018). Example applications are state vector agent computing model, c.f. (Nourani and Lauth-Pedesen, 2015): CBS, Denmark. State agent vectors F1,…,Fn span a BM viewing Section 5.1. The state space is a Boolean valued matrix on model game trees t1,…tn, for a dynamic state-space agent vectors.

Agent decision tree matrix is as follows, with each ti being mapped either F,T, or X: the indetermined symbol, by a computation sequence on the state space vector machine. X entries are resembling "Don't care" symbols in Karnaugh Maps.

F1: t1,….tn
F2: t1,…,tn
Fm: t1,….,tn)

The sparse matrix determines how the keyed database will minimize the relevant big data sectors. A sparse matrix is a matrix that allows special techniques to take advantage of the large number of "background" (commonly zero or, in our case, indeterminant X elements).

The number of zeros a matrix needs in order to be considered "sparse" depends on the structure of the matrix and the desired operations to perform on it. For example, a randomly generated sparse matrix with entries scattered randomly throughout the matrix is not sparse in the sense of Wilkinson (for direct methods) since it takes time to factor. The computation sequences on our competitive model techniques are Boolean matrix multiplications on sparse matrices. Applying for example, Strassen matrix multiplications, we have newer algorithms for sparse minimizing big data areas to reach on a database.

5.5.6 SAS EXAMPLE ANALYTICS: BUILDING PREDICTIVE ANALYTICS MODELS

On the pragmatics for descriptive analytics, that is the nature of data in terms of historical behavior and trends, forward onto predictive analytics: attempting to discover what might happen in the future based on the historical data, involves building models to represent the relationships between input variables and a target of interest. Using such models to classify new observations or predict target values is, of course, the focus of ML. One of the goals of SAS visual data mining and ML is to offer these modeling capabilities in different forms that can be consumed by users who have various levels of expertise. One may wish to compare that also to TAIM (Nourani, 2001), or the volume on AA Press (Nourani, 2018) SAS Visual Analytics has goals for interactive accomplishments with no programming required. So what is presented in this chapter might be an area that can be explored with SAS.

A crucial step in building predictive models is to ensure that you hold out data from the training process to access the accuracy of the model. So competitive models are important for this purpose (Figure 5.3).

5.6 AGENTS, MODULES, AND ALGEBRAS

5.6.1 COMPUTING ON TREES

To present some motivation for the methods proposed, certain model-theoretic concepts are reviewed and some new techniques are presented. The Henkin style proof for Gödel's completeness theorem is implemented by defining a model directly from the syntax of theories. A model is defined by putting terms that are provably equal into equivalence classes, then defining a canonical structure on the equivalence classes. The computing enterprise requires more general techniques of model construction and extension since it has to accommodate dynamically changing world descriptions and theories. The models to be defined are for complex computing phenomena, for which we define generalized diagrams.

The author's techniques for model building (e.g., Nourani, 1991, 1996) as applied to the problem of AI reasoning allows us to build and extend

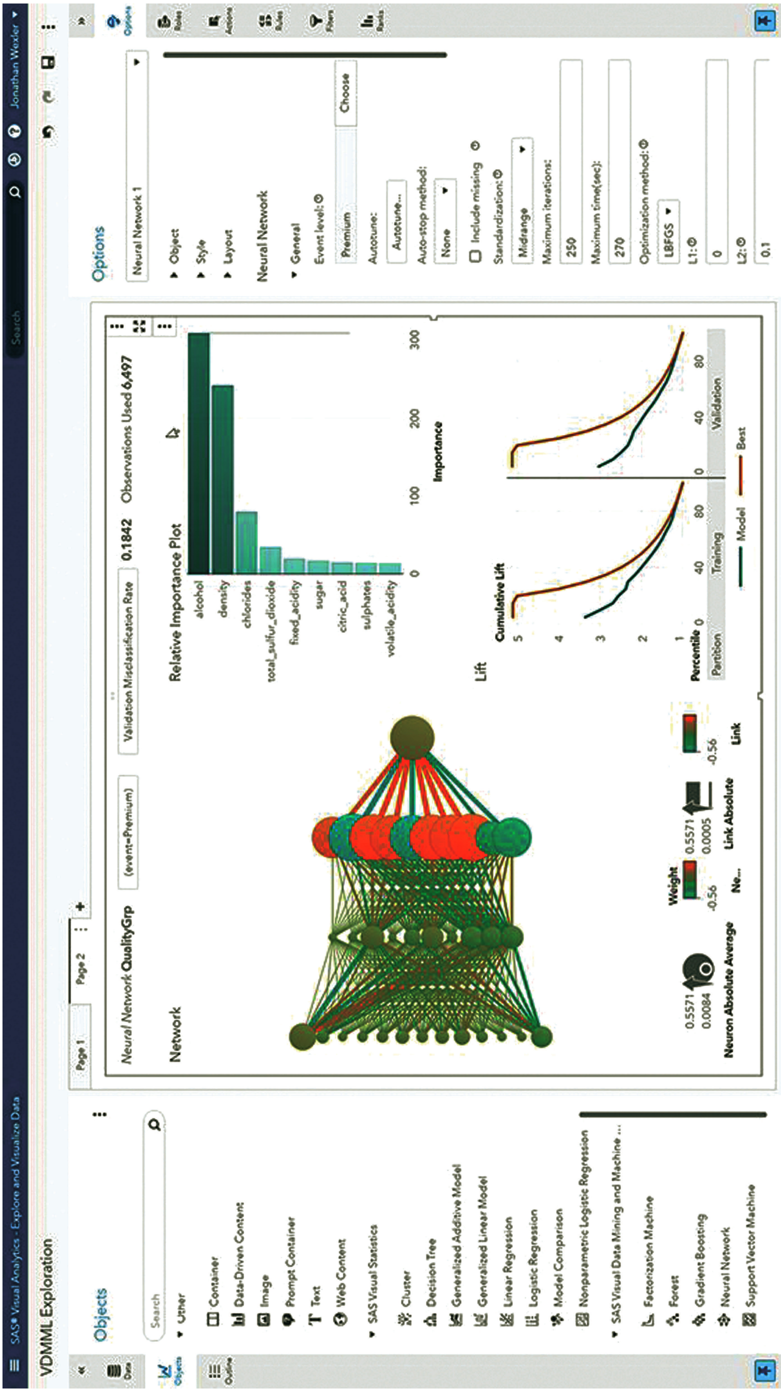

FIGURE 5.3 Interactive analytics example.
Source: Reprinted from Gupta, 2018. © 2018, SAS Institute Inc.

models through diagrams. This required us to focus attention on generic model diagrams. The minimal set of function symbols is the set with which a model can be inductively defined. The models are standard and computable.

The generic diagram methods allowed us to formulate AI world descriptions, theories, and models in a minimal computable manner. Thus models and proofs for AI and computing problems can be characterized by models computable by a set of functions. It allows us to program with objects and functions "running" on G-diagrams. To allude to our AI planning techniques as an example, the planning process at each stage can make use of generic diagrams G-diagrams with free Skolemized trees, by taking the free interpretation, as tree-rewrite computations for the possible proof trees that correspond to each goal satisfiability. Suppose there are some basic Skolem functions f1…,fn that define a G-diagram. During planning or proof tree generation a set of Skolem functions g1…,gn could be introduced (Nourani, 1995). While defining such free proof trees, a set of congruence relations relates the g's to the f's. The proofs can make use of the tree congruence relations, or be carried out by tree rewriting, thereby having 'free proof trees'.

The computing and reasoning enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. The techniques in the author's projects for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. A technical example of algebraic models defined from syntax had appeared in defining initial algebras (ADJ, 1977) for equational theories of data types (Nourani, 1980, 1996). In such direction for computing models of equational theories of computing, problems are presented by a pair (S,E), where Σ is a signature (of many sorts, for a sort set S) and E a set of S-equations. Let T<S> be the free tree word algebra of signature Σ. The quotient of T<S>, the word algebra of signature S, concerning the S-congruence relation generated by E, will be denoted by T<S,E>, or T<P> for presentation P. T<P> is the "initial" model of the presentation P.

The S-congruence relation will be denoted by ºP. One representation of T(P) which is nice in practice consists of an algebra of the canonical representations of the congruence classes, abbreviated by S-CTA. It is a special case of generalized standard models the author had defined (Nourani, 1996) for newer examples of agent signature decision trees. Some definitions are applied from the papers that allow us to define standard models of theories that are SCIA's. The standard models are significant for tree computational theories that the author had presented. Generic diagrams are applied to define canonical standard models in the same sense as set theory. This definitions are basic to sets and in defining induction for abstract recursion and inductive definitions. We had put forth variants of it with axiomatizations in our papers. The definitions were put forth by the first author for the computability with initial models. The canonical models are applied to multiagent computing during the last several years by the author.

5.6.2 AGENT AUGMENTED LANGUAGES

The computing enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. The models to be defined are for complex computing phenomena, for which we define generalized diagrams. The techniques this author presented since the 1990′s or before for model building for initial tree algebras with generic model diagrams is applied to the problem of AI reasoning allows us to build and extend models through diagrams. It required us to define the notion of generalized diagram. G-diagrams build models with prespecified generalized Skolem functions. The specific minimal set of function symbols is the set with which a model for a knowledge base can be defined.

The G-diagram techniques allowed us to formulate AI worlds, KB's in a minimal computable manner to be applied to agent computation. The techniques in Nourani (1991, 1994a) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. A technical example of algebraic models defined from syntax had appeared in defining initial algebras for equational theories of data types (ADJ, 1973) and our research in Nilsson (1969). In such direction for computing models of equational theories and canonical term algebras for computing problems are presented by a pair (Σ,E), where is a signature (of many sorts, for a sort set S, and E a set of -equations (ADJ, 1973, 1979; Nourani, 1995a). To have a specific agent functions processes in mind let us brief on a specific agent machine that was first presented by Geneserth-Nilsson (1987) that has been applied by Nourani (1994–2005) for agent computing examples.

5.6.3 ABSTRACT AGENT PROCESSING MACHINES

Starting with what are called hysteretic agents (Genesereth and Nilsson, 1987). A hysteretic agent has an internal state set I, which the agent can distinguish its membership. The agent can transit from each internal state to another in a single step. Actions by agents are based on I and board observations.

There is an external state set S, modulated to a set T of distinguishable subsets from the observation viewpoint. An agent cannot distinguish states in the same partition defined by a congruence relation.

A sensory function s:S → T maps each state to the partition it belongs. Let A be a set of actions that can be performed by agents. A function action can be defined to characterize an agent activity action: T →A. There is also a memory update function mem: I × T → I. To define agent at arbitrary level of activity knowledge level agents are defined. All excess level detail is eliminated. In this abstraction, an agent's internal state consists entirely of a database of sentences, and the agent's actions are viewed as inferences based on its database. The action function for a knowledge level agent maps a database and a state partition t into the action to be performed by an agent in a state with database and observed state partition t.

$$\text{Action: } D \times T \rightarrow A$$

The update function database maps a state and a state partition t into a new internal database.

$$\text{Database: } D \times T \rightarrow D$$

A knowledge-level agent is an environment is an 8-tuple shown below. The set D in the tuple is an arbitrary set of predicate calculus databases, S is a set of external states, T is the set of partitions of S, A is a set of actions, see is a function from S into T, do is a function from A S into S, database is a function from D × T into D, and action is a function from D × T into A.

Since 1995 (Nourani, 1995), we say that a language has intelligent syntax if the syntax is defined on an intelligent signature.

To define a specific mathematical linguistics basis for agent augmented languages intelligent languages were defined (Nourani, 1995d) as follows:

- **Definition 5.1:** Let us say that a signature is intelligent iff it has intelligent function symbols.
- **Remark:** The notion of an intelligent signature is simply a designation that there is a sub signature with specific properties, for example, all the functions are 1-1.
- **Definition 5.2:** A language L is said to be an intelligent language iff L is defined from an intelligent syntax.

Agent augmented languages and signatures allow us to present computational theories with formulas on terms with intelligent function symbols.

- **Definition 5.3:** We say that a function f is a string function, if there is no message passing or information exchange except onto the object that is at the range set for f, reading parameters visible at each object. Otherwise, f is said to be a splurge function. We refer to them by string and splurge functions when there is no ambiguity.
- **Remark:** Nullary functions are string functions.
- **Definition 5.4:** The tree intelligence degree, TID, is defined by induction on tree structures:

  (0) the intelligence content of a constant symbol-function f is f.

  (i) for a string function f, and tree f(t1.,tn) the TID is defined by:

  U TID (ti::f)

  where; (ti::f) refers to a subtree of ti visible to f.

  (ii) for a splurge function f, TID is defined by:

  U TID (f:ti).

  where; f:ti refers to the tree resulting from ti upon information exchange by f. _

There are implicit mobile object computing principles at Definition 5.2, for example, the concept of a subtree being visible to a function, and of course, agents. The theorem below formalizes these points. Thus out of the forest of intelligent trees there appears an information-theoretic rewrite theorem.

- **Definition 5.5:** We say that an equational theory T of signature I is an intelligent IΣ theory iff for every proof step involving tree rewriting, the TID is preserved. We state T<IST> |- t = t' when T is an IS theory. _
- **Definition 5.6:** We say that an equational theory T is intelligent, if T has an intelligent signature IS, and axioms E, with IΣ its intelligent signature. A proof of t = t' in an intelligent equational theory T is a finite sequence b of IΣ-equations ending in t = t' such that if q = q' is in b, then either q = q' in E, or q = q' is derived from 0 or more previous equations in E by one application of the rules of inference. Write T <IST>|-t = t' for "TP proves t = t' by intelligent algebraic subtree replacement system."

  By definition of such theories, proofs only allow tree rewrites that preserve TID across a rule. These definitions have been applied to prove the theorems, set up the foundations for intelligent tree rewriting and intelligent tree computation (Nourani, 1996).

- **Definition 5.7:** A tree defined from an arbitrary signature Σ is intelligent if there is at least one function symbol g in Σ such that g is a member of the set of intelligent functions AFS, and g is a function symbol that appears on the tree.
- **Definition 5.8:** We define an intelligent S-equation, abbreviate by IS-equation, to be a S-equation on intelligent Σ-terms. A IS-congruence is a S-congruence with the following conditions:
  i. The congruence preserves IS-equations;
  ii. the congruence preserves computing agent's intelligence content of Σ-trees. _

Canonical models are definable with canonical sets C on the carriers with <function, base-set> pair by recursions such that C with a set of tree rewrite rules R represents T<IS,~R>, where ~R is the set R of axioms for P viewed as IS-rewrite rules.

- **Definition 5.9:** Let Σ be an intelligent signature. Then a canonical term IS-algebra (IS-CTA) is a S-algebra C such that:
  1. |C| is a subset of T<S> as S-indexed families.
  2. gt1.tn in C implies ti's are in C and; gC (t1.,tn) = gt1.tn, where gC refer to the operation in algebra C corresponding to the function symbol g, for constant symbols (2) must hold as well, with gC = g.
  3. gt1.tn in T<AFS> implies ti's in C and gC(t1.,tn) = gt1.tn; for constant symbols it must hold as gC = g.

Thus we have the following Canonical Intelligent Model Theorems. The theorems provide conditions for automatic implementation by intelligent tree rewriting to initial models for programming with objects.

- **Theorem 5.1:** Let C be an IS-algebra. Let P = (S,E) be a presentation. Then C is isomorphic to T<P>, iff:
  i. C satisfies E;
  ii. gC (t1.,tn) ºP g.t1.tn.
  iii. gC(t1.,tn)ºP gt1.tn, with gt1.tn in T<AFS> whenever ti's are in T<AFS> and gC is in AFS.

Note: (ii and iii) must also hold for constants with g. C = g; ≡ refers to the IΣ-congruence generated by E;.

- **Proof:** Nourani (1996) states sufficient conditions for constructability of an initial model for an IΣ equational presentation from the above proposition. It is the mathematical justification for the proposition that initial models with intelligent signature can be automatically implemented (constructed) by algebraic subtree replacement systems. The normal forms are defined by a minimal set of functions that are Skolem functions or type constructors.

  The intelligent languages basis (Nourani, 1995d) defines intelligent context free grammars as follows.
- **Definition 5.10:** A language L is intelligent context free, abbreviated by ICF, if L is intelligent and there is a context free grammar defining L.

  A preliminary parsing theory might be defined once we observe the correspondence between String Functions and context. Let us define string intelligent functions.
- **Definition 5.11:** A language is String Intelligent iff it is an intelligent language and all agent functions in the language are 1-1 functions. The following starts ICF.

  The following start to the ICF theory is from ECAI (Nourani, 1994).
- **Theorem 5.2:** Let L be a context-free language with signature S. Let L* be a string intelligent language extending L such that L* has the same signature as L, except for string agent function symbols augmenting L's signature. Then L* is ICF.

  The proof outline is that there is an initial algebra TΣ that is defined direct from a context free grammar's (ADJ, 1973) productions. The string agent functions on 1-1 therefore there is an embedding homeomorphism preserving the TS context-free trees. Agent morphisms are defined in, e.g., on ontologies for heterogenous computing since 1994, c.f. (Nourani, 2005) briefed on the following section here.

5.6.4 ABSTRACT INTELLIGENT SYNTAX ON OBJECT COMPUTING

The examples of agent augmented languages we could present have <O,A,R> triples as control structures. The A's have operations that also consist of agent message passing. The functions in AFS are the agent functions capable of message passing. The O refers to the set of objects and R the relations defining the effect of A's on objects. Amongst the functions in AFS only some interact by message passing. What is worse, the functions could affect objects in ways that affect the intelligence content of a tree. There you are: the tree congruence definition thus is more complex for agent augmented languages than those of ordinary syntax trees. Let us define tree intelligence content for the present formulation.

The computing enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. The models to be defined are for complex computing phenomena, for which we define generalized diagrams. The techniques in Nourani (1983, 1987, 1991, 1994a) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. It required us to define the notion of generalized diagram. We had invented G-diagrams (Nourani, 1987, 1991, 1993b, 1994a) to build models with prespecified generalized Skolem functions. The specific minimal set of function symbols is the set with which a model for a knowledge base can be defined. The G-diagram techniques allowed us to formulate AI worlds, KB's in a minimal computable manner to be applied to agent computation.

The techniques in Nourani (1991) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. A technical example of algebraic models defined from syntax had appeared in defining initial algebras for equational theories of data types (ADJ, 1973) and our research in Nilsson (1969). In such direction for computing models of equational theories of computing problems are presented by a pair (Σ,E), where is a signature (of many sorts, for a sort set S) (ADJ, 1973; Nourani, 1995a) and E a set of -equations. Signatures are in the same sense as key signatures in music. The notion of an intelligent signature is simply a designation that there is a sub signature with specific properties, for example, all the functions are 1-1.

The example of intelligent languages are composed from <O,A,R> triples as control structures (e.g., Nourani, 1993): Surf Florida. The functions in AF are the agent functions capable of message passing. The O refers to the set of objects and R the relations defining the effect of A's on objects. Amongst the functions in AF, only some interact by message passing. The functions could affect objects in ways that affect the information content of a tree. There you are: the tree congruence definition thus is more complex for intelligent languages than those of ordinary syntax trees. Let us define tree information content for the present formulation.

Hence there is a new frontier for a theoretical development of the <O,A,R> algebras and that of the AII theory. <O,A,R> is a pair of algebras, <Alg[A],Alg[F]>, connected by message passing and AII defines techniques for implementing such systems. To define AII we define homomorphism intelligent signature algebras.

5.7 MORPH GENTZEN

The IM Morphed Computing Logics for computing for multimedia are new projects with important computing applications since 1997 (Nourani, 1997). The basic principles are a mathematical logic where a Gentzen or natural deduction systems is defined by taking arbitrary structures coded by diagram functions. The techniques can be applied to arbitrary topological structures. Thus we define a syntactic morphing to be a technique by which infinitary definable structures are homomorphically mapped via their defining functions to new structures. The deduction rules are a Gentzen system augmented by two rules morphing and trans-morphing. The Morph Rule-A structure defined by the functional n-tuple can be Morphed to structures definable by the functional n-tuple, provided h is a homeomorphism of abstract multiagent signature structures (Nourani, 1994, 1996).

The TransMorph Rules-A set of rules whereby combining structures A1…,An defines an Event {A1,A2.,An} with a consequent structure B. Thus the combination is an impetus event. The deductive theory is a Gentzen system in which structures named by parameterized functions; augmented by the morph and trans-morph rules. The structures we apply the Morph logic to are definable by positive diagrams. The idea is to do it at abstract model's syntax trees without specifics for the shapes and topologies applied. We start with Lω1,ω and further on might apply well-behaved infinitary languages. Theorem 5.1 Soundness and Completeness-Morphed Gentzen Logic is sound and complete. Proof outline Plain Morph Gentzen Logical Completeness has two proofs: A-There is a direct proof which applies positive diagrams, and canonical models for Lω1,ω fragments as the authors' papers in mathematical logic. B-There is a conventional proof route whereby we start with the completeness theorem for ordinary Gentzen systems. From it we can add on the morph rules and carry out a proof based on what the morph rules preserve on models. Again intricate models are designed with positive diagrams.

5.7.1 VISUAL AND VIRTUAL TREES

Linguistics KR and its relation to context abstraction are defined in brief. Nourani (1999a) has put forth new visual computing techniques for intelligent multimedia context abstraction with linguistics components. In the present paper, we also instantiate proof tree leaves with free Skolemized trees. Thus virtual trees, at times like intelligent trees, are substituted for the leaves. By a virtual tree, we mean a term made up of constant symbols and named but not always prespecified Skolem function terms. In virtual planning with G-diagrams that part of the plan that involves free Skolemized trees is carried along with the proof tree for a plan goal. We can apply predictive diagram KR to compute queries and discover data knowledge from observed data and visual object images keyed with diagram functions. Model-based computing (Nourani, 1998c) can be applied to automated data and knowledge engineering with keyed diagrams. Specific computations can be carried out with predictive diagrams (Nourani, 1995a).

For cognition, planning and learning the robot's mind, a diagram grid can define state. The starting space applicable project was meant for an autonomous robot's space journeys. The designs in the author's papers are ways for a robot to update its mind state based on what it encountered on its path.

That what the robot believes can be defined on a diagram grid. The degree to which a robot believes something is on the grid. It can get strengthened or weakened as a function of what the robot learns as progress is brought on. Robot's Mind State: The array grid entries are pointing to things to remember and the degree the robot believes them. The grid model is a way to encode the world with the model diagram functions. Canonical models from models to set theory had been stated for arbitrary structures as follows.

5.7.2 MULTIAGENT VISUAL PLANNING AND LEARNING

Let us define what Morph Gentzen sequent modeling is.

- **Definition 5.12:** An IS-homomorphism is a homomorphism defined on algebras with intelligent signature IS.
- **Definition 5.13:** Let A and B be IS-algebras with signatures containing an agent signature HA. A HA-homomorphism from A to B is an IS-homomorphism that preserve a designated HA signature trees properties, e.g., HA-terms preserves 1-1 properties on agent signature terms.
- **Definition 5.14:** An IS-algebras is a Model A for a Morph Gentzen sequent p iff:
    - i. Every constant symbol a in signature S has a corresponding constant in A;
    - ii. Every IS-term f(t1,…t,n) has a corresponding n-ary function definable at A;

iii. Every IS-equation defined at A with terms on A;
iv. Every IS-equation is valid in A.

- **Remark:** On the agent process model instantiations: for the agent function symbols on the IS signature the IS must ensure that the model A has an agent process function well-defined, e.g., as a hysteretic agent according to the agent state machine presented in Section 5.6.3, or a comparable assignment for the functions on the agent signature. Essentially each sequent instance is a state on an abstract agent machine that assign values or a Skolem term for the agent signature function in A.

  The above remark might be further considered an agent ontology structural characterization (Nourani, 2005; Nourani-Eklund, 2017).
- **Theorem 5.3:** An IS-algebras is a model for a Morph Gentzen sequent p iff there is a canonical IS-algebra definable on a generic IS-tree diagram for p.
- **Proposition 5.1:** Morph Gentzen and Intelligent languages provide a sound and complete logical basis to VR.
- **Proof:** (c.f. Nourani, 2005, 2018 volumes on Intelligent Multimedia Computing Science ASP 2005 and AA Press volume on Predictive Analytics, Chapter 12).

5.7.3 VIRTUAL TREE PLAN MODELS

Canonical models from models to set theory had been stated for arbitrary structures as follows:

- **Definition 5.15:** A Generic diagram for a structure M is a diagram such that there is a proper diagram definition with specific function symbols, for example, Σ Skolem function.

  The idea is that if the free proof tree is constructed for a goal formula, the Generic diagram defines a model satisfying the goal formula satisfied. This theorem is from Nourani (2018) AA Press Volume on Predictive Analytic Chapter 12.
- **Theorem 5.4:** For the virtual proof trees defined for a goal formula from the Generic diagram, there is an initial model satisfying the goal formulas. It is the initial model definable by the Generic diagram.
- **Proof:** (Restated for completeness from, for example, Nourani (2005)). In planning with GF-diagrams, plan trees involving free Skolemized trees are carried along with the proof tree for a plan goal. The idea is that if the free-proof tree is constructed, then the plan has

a model in which the goals are satisfied. There is an analogy to SLD proofs. We can view on the one hand, SLD resolution type proofs on ground terms, where we go from p(0) to p(f(c)); or form p(f(c)) to p(f(g(c)). Whereas, while doing proofs with free Skolemized trees we are facing proofs of the form p(g(.)) proves p(f(g(.)) and generalizations to p(f(x)) proves For all x, p(f(x)). Since the proof trees are either proving plan goals for formulas defined on the GF-diagram, or are computing with Skolem functions defining the GF-diagram, the model defined by the GF-diagram applies and it is initial for the proofs.

For free Skolemization, what comes to our logician mind's side of things is Generic model expansion. It is relevant to our methods of modeling, planning, and reasoning. A free proof tree is a proof tree that is constructed with free Skolem functions and GFS from a GF-diagram. The idea is that if the free proof tree is constructed for a goal formula, the GF-diagram defines a model satisfying the goal formula satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed. Thus we have transformed the model-theoretic problems of computing to that of defining computing with Generalized Diagrams. There are recent papers since 1992 (ADJ, 1973; Nourani Hoppe,1994), where we have presented this theory and technique. Partial deductions in the present approach correspond to proof trees that have free Skolemized trees in their representation. In the present approach, the free proof tree technique, as we shall further define, leaves could be virtual, where virtual leaves are free Skolemized trees.

The model is the initial model of the AI world for which the free Skolemized trees were constructed. For plans with free Skolmized trees, we can apply the Hilbert epsilon technique to define computing models. What applying Hilbert's epsilon implies is that there is a model M for the set of formulas such that we can take an existentially quantified formula w[X] and have it instantiated Skolem function that can answer the membership question to the model. Whether or not Hilbert had intended it this way or not is not relevant at present. The issue in our approach, however, is that we are not so much concerned with existentially quantified formulas. We start with some Skolem functions to define Initial models.

Thus we have Hilbert models for which the Skolem functions implicitly define membership to the set defining a model. We have planning applications with VR in which there is goal formula to be satisfied with perhaps existential quantifiers. Since we are interested in model-theoretic techniques for handling proofs with the method of free proof trees, we propose the following model-theoretic view, which we refer to by the Hilbert Model Theorem for Skolemized virtual tree computing.

- **Theorem 5.5:** Hilbert's epsilon technique implies there is a model M for the set of formulas such that we can take an existentially quantified formula w[X] and have it instantiated by a Skolem function which can answer the satisfiability question for the model.
- **Proof:** (e.g., Nourani, 2018: AA Press volume, Chapter 12).

5.8 A VISUAL COMPUTING ON A SEQUENT ANALYTIC TABLEAUX

The project is towards new analytics based on Tableau computable Morph Gentzen sequent proof. In the papers, diagrams for cognitive modeling are applied and scientific techniques are applied towards discovery and consciousness science (Nourani, 1999). Morph Gentzen comes close to human experience in attaining proofs. At the base of its empirical intuition lies a pure intuition which is a priori. Frege's basic logical ideas and Hilbert's program separate carrying out pure mathematics from the physical cognition perceptions of what is carried out as an end. Frege's "concept and object" and on "sense and meaning," is where carrying out logic for objects named by a language had started being distinguished from the object sense perception. Hilbert's program, aside from its being left to reconcile with transcendental idealism on concepts, were to aromatize the entire mathematics. Where are we with descriptive computing Heidegger objects? We are at the language, model, arithmetization trichotomy. The objects are described with languages as Frege intended, modeled by structures, which can be examined by Kan't transcendental idealism, and their computability and reducibility areas Hilbert arithmatized. Hence there is a systematic basis to carryout concept-object descriptions for machine discovery. Following Beth (1970) and Nourani (2000) on descriptive definability for the Tableau models, we have the following:

- **Proposition 5.2:** (Tableaux Sequent Models) A structure models a morph sequent iff (a) the structure models the initial antecedent to the sequent and (b) the sequent is explicitly definable by Φ{P1,…,Pn}, where Φ{P1,…,Pn} is the set if sentences of the language

L∪{P1,…,Pn}; and P1,…,Pn are n-placed relation symbols for relations defining the Skolem functions available on the structure, applied by the sequent.

- **Proof:** Follows from the definition for explicit definability, Morph Gentzen completeness (proved for example on Nourani (2018) AA Press volume Chapter 12.
- **Theorem 5.6:** A set of formula Λ's validity is preserved by an arbitrary morph sequent with functions appearing in Λ iff Λ is provable on the tableaux for the respective language.
- **Proof:** Follows from the above proposition and the tableaux model descriptive computability (Nourani, 1997).

5.8.1 INCOMPLETE MODEL DIAGRAMS

According to Poole et al. (1987), an explanation problem can be stated formally as: given Facts Φ consistent formulas, known to be true, Defaults Δ: possible hypotheses, that we accept as part of an explanation and Observations G: which are to be explained, An observation g in G is explainable, if there exits ground hypotheses Ω⊂Δ, such that:

1. $\Phi \cup \Omega \models g$; and
2. $\Phi \cup \Omega$ is consistent.

Examples base set applications: closed-world assumption (CWA) and nonmonotonic logics. Base set Δ. T(Δ) is the closure of T under logical entailment. Suppose Δ includes the following:

Thing (Tweedy); Bird(x) → Thing(x); Ostrich(x) → Bird(x) Flying-Ostrich(x) → Ostrich(x).

For example, if we want to state that nothing except for birds can fly, that is all birds, except ostriches fly and that no ostriches, except for flying ostriches can fly, we can do that with the following:

Thing(x) & not Bird(x) → not flies(x) Bird(x) & not ostrich(x) → Flies(x) Ostrich(x) & not flying-ostrich(x) → not Flies(x) Flying-ostrich (x) → Flies(x) Thing(x) & not Bird(x) & Ostrich(x) & not Flying-ostrich not (x) Bid(x) flying-ostrich(x) → ostrich(x).

Examples base set applications: CWA and nonmonotonic logics.

Base set Δ. T(Δ) is the closure of T under logical entailment. Suppose Δ includes the following:

Thing (Tweedy); Bird(x) → Thing(x); Ostrich(x) → Bird(x)

Flying-Ostrich(x) → Ostrich(x)

For example, if we want to state that nothing except for birds can fly, that is all birds, except ostriches fly and that no ostriches, except for flying ostriches can fly, we can do that with the following.

Thing(x) & not Bid(x) → not Flies(x)
Bird(x) & not Ostrich(x) → Flies(x)
Ostrich(x) & not Flying-Ostrich(x) → not Flies(x)
Flying-ostrich (x) → Flies(x)

Theorist is a proof procedure for predictive reasoning based on Loveland Meson (1978) system that Poole et al. have further developed. This author has carried that area on virtual trees and partial deduction since 1992, e.g., (Nourani-Hoppe, 1995; Nourani, 2014). Minimal prediction on virtual tress constructs hypotheses on generic Skolemized trees, where each hypothesis is a set of atomic literals Δi; such that when some particular theory T is augmented with Δi, it entails the set of goal literals G, where entailments are carried on with virtual trees that are modeled on generic model diagrams. Therefore, T ⊨ Δi U G. Δi must be a subset of a set of ground atomic virtual tree predictable A. In addition, we must ensure T U Δi is consistent under ⊨. The set of all possible hypotheses is ⊨{Δi}. More general predictions are defined by applying more complex virtual tree parametrized formulas as predictable based on generic model diagrams. First-order existential formulas can form the predictable.

- **Theorem 5.7:** Compactness A formula A in a theory T is valid iff it is valid in some finitely axiomatized part of T.
- **Corollary 6.1:** A theory T has a model iff every finitely axiomatized part of T has a model.
- **Theorem 5.8:** A set of first-order observations G is explainable iff there exists a predictive diagram for the logical consequences to G.
- **Proof:** Applies the above with Gödel's completeness and the compactness theorem from model theory.

  (→) The diagram D[M], where M is a model for T, and for any formula q in M, indicates either the function f: q → {0,1} is defined, or there exists a formula p in D[M], such that T ∪ {p} ⊢ q; or that T proves q by minimal prediction. Hence for a formula g there exits ground hypotheses Ω ⊆ Δ on which f: q → {1,0} is defined such that T ∪ p ⊢ g; or there exists a formula p such that T ∪{p} proves q, or T proves q my minimal prediction, hence the compactness Theorem 5.1 renders T ∪ Ω consistent. Thus g in G explainable.

(←) When g U ϕ is explainable, there exist ground hypotheses $\Omega \subseteq \Delta$ such that:

1. $T \cup \Omega \models g$;
2. $T \cup \Omega$ is consistent.

Therefore, either there is a function f: g→ {1,0} defined directly; or by applying Gödel's completeness theorem a time or two, there is a proof for g either direct or by minimal prediction. Therefore, there is a predictive diagram for the logical consequences to G. _

5.8.2 INTERACTIVE VISUAL ANALYTICS WITH INCOMPLETE MODEL DIAGRAMS

The author's publications (Nourani, 2003) have proved that a set of first-order observations ϕ is reconcilable with the model iff there exists a predictive diagram for the logical consequences to ϕ.

Here Morph Gentzen deductions are applied to explain a Tableaux consequent.

An explanation problem can be stated formally as given:

Facts Φ: Consistent formulas, known to be true;
Defaults Δ: Possible hypotheses, that we accept as part of an explanation;
Observations G: Which are to be explained.

An observation g in G is explainable, if there exits ground hypotheses $\Omega \subseteq \Delta$ such that:

1. Φ U $\Omega \models g$; and
2. Φ U Ω is consistent.

To state-specific applications, let us state the compactness theorem from standard logic and model theory. Let us say that a prediction is minimal iff the predictive hypothesis are based on a minimal subsets of $\Theta \cap \Delta$.

Let us present a basic for interactive analytics that is entailed from the above, however, with Morph Gentzen sequent.

Considering sequent on the tableau model theorem A set of formula Λ's validity is preserved by an arbitrary morph sequent with functions appearing in Λ iff Λ is provable on the tableaux for the respective language. Every picture pi on a sequent has and an agent and object presentation algebra (e.g., Nourani, 1996, 2018: Chapter 12). Let us call that the virtual presentation algebra for a morph Gentzen sequent. By the tableau sequent theorem above, we can state a Morph Gentzen compactness theorem as follows.

The Morph Gentzen computing structures are algebraic agent signature tree structures admitting initial models (e.g., Nourani, 1996). The ordinary signature tree structures were first presented by ADJ (1977). The agent structure algebras are due to the present author (e.g., Nourani, 1996).

- **Definition 5.16:** Let (M,a)c in C be defined such that M is a structure for a language L and each constant c in C has the interpretation a in M. The mapping c → ac is an assignment of C in M. We say that (M,a)c in C is canonical model for a presentation P on language L, iff the assignment c→ a maps C onto M, i.e., M = (a:c in C).

  Generic diagrams allow us to define canonical models with specific functions.

  How we present agent structures with agent signature trees allows us to morph sequent on the structure while preserving the basic initial morphic properties based on well-behaved infinitary language fragments. Therefore, we have sequent compactness properties as follows.
- **Proposition 5.3:** (Morph compactness) a morph Gentzen sequent p1,…,pn, n ∈ ω has a tableau model every finite sequent on pi has tableau sequent models.
- **Proof:** Follows from Theorem 5.1, the canical ISL algebra theorem, and the compactness Theorem 5.7

  The above proposition is the basis for explaining an interactive analytic process.
- **Theorem 5.9:** A Morph Gentzen sequent MG is explainable iff there exists a predictive model diagram for the logical consequences to MG.
- **Remark:** That says we can have an explanation for a visual analytics picture based on comprehensive logical consequences. A model diagram for a sequence is essentially a generic encoding for the sequent Tableaux model (Theorem 5.1).

5.9 COMPETITIVE MODELS, PREDICTIVE MODEL DIAGRAMS, AND MODEL DISCOVERY

5.9.1 BUSINESS MODEL (BM) DIGITIZATION WITH FUNCTIONS

KR has two significant roles: to define a model for the AI world, and to provide a basis for reasoning techniques to get at implicit knowledge. An ordinary diagram is the set of atomic and negated atomic sentences that are true in a model. Generalized diagrams are diagrams definable by a minimal set of functions such that everything else in the model's closure can be inferred by a minimal set of terms defining the model. Thus providing a minimal characterization of models, and a minimal set of atomic sentences on which all other atomic sentences depend. We want to solve real-world problems in AI. Obviously, for automating problem-solving, we need to represent the real world. Since we cannot represent all aspects of a real-world problem, we need to restrict the representation to only the relevant aspects of the real world we are interested in. Let us call this subset of relevant real-world aspects the Relevant World for a problem.

AI approaches to problem-solving represent the knowledge usually in some kind of the first-order language, consisting of at least constants, function, and predicate symbols.

Our primary focus will be the relations amongst KR, AI worlds, and the computability of models truth is a notion that can have dynamic properties. A formalization of problem-solving knowledge (we refer to it from now on with the term: theory) is not independently true. Neither is a consequence inferred from a theory true independently. The sets of sentences defining a theory are only true with respect to a certain world. This insight has found its theoretical counterpart in model theory, which fixes the semantics of a language (most often first-order logic (FOL)) with respect to a certain world by means of an interpretation function. Interpretation functions map language constructs (constants, function, and predicate symbols) onto entities of the world and determines the notion of truth for individuals, functions, and relations in the domain. The real world is infinite, as are AI worlds at times. To keep the models which need to be considered small and to keep a problem tractable, such that the models could be computable and within our reach, are important aspects. Related questions are also taken up in another area of research by Nourani (2005). We show that we can apply generic diagram functions to localize reasoning to the worlds affected by some relevant functions to a specific reasoning aspect.

The digital economy has produced an enormous amount of data, but very little of it has been analyzed. That leaves a huge opportunity for business growth, with SAP HANA and Intel, for example, plan to boost the SAP platform that underpin its enterprise applications, including: real-time in-memory computing, streaming, and big data analytics, blockchain augmented and virtual reality, ML and AI. Our data filtering (Nourani, 2018), deep digitization with sparse heuristics (e.g., AA Press Vol., 2018), on for augmented reality (Nourani and Meceir-Lauent, 2020) have contributed the areas during the past decade.

The areas where we have applied Generic diagrams include formal theories of Diagrammatic Reasoning (e.g., Nourani, 1992; Galsgow et al., 1995), Computational models of, the synergy between Cognitive theories, formal theories, and computational models. Applications to multimedia computing are presented in Nourani (2005), for example. What are the advantages to apply Generic diagrams for KR compared to what has been applied thus far, e.g., semantic nets, conceptual graphs, first-order clauses? The answer is since our computation techniques and planning goals are based on models we have found our techniques to be most suitable. Other forms of KR are not suited for automatic model generation and planning techniques with model theory and do not have our method of Skolemized proofs trees. Furthermore, we can apply the same techniques to automatic model discovery from presented knowledge. New applications to explanations are stated with a completeness theorem. Model and proof computations are carried out, presenting an Initial proof-tree goal-model theorem. Model discovery computation as plan proof trees and proof abstraction techniques are presented in brief. Basic forecasting agent computing applications were presented by the author at AAAI (Nourani, 1992).

5.9.2 REACHING FOR DEEP KNOWLEDGE WITH DIGITIZATION

The computing reasoning enterprise requires more general techniques of model construction and extension, that was available since Gödelś completeness proof that was proved by Henkin by a very clever first-order language terms for instantiations. The computing enterprise has to accommodate dynamically changing world descriptions and theories. The techniques in for example in Nourani (1985, 1992) for model building as applied to the problem of AI reasoning allows us to build and extend models with digitized model diagrams. This requires us to define the notion of generalized diagram. The diagrams are used to build models with a minimal family of generalized Skolem functions. The minimal sets of function symbols are those with which a model can be built inductively. Such models are categorical Initial and computable. The Generic diagram methods applied and further developed here, allows us to formulate AI world descriptions, theories, and models in a minimal computable manner. It further allows us to view the world from only the relevant functions.

Thus models and proofs for AI problems can be characterized by models computable by a set of functions. Reflecting on IBM on the real-world applications goals of the interplay between ML and smarter decision optimization at the IBM Think 2018 conference., Faster, The Decisions by combining ML and decision optimization, IBM's decision optimization for Watson Studio: Predict Maintenance Needs to Keep Production Going) that allows you to explore creating innovative solutions that combine ML and decision optimization.

As companies wake up to the potential of AI applications, data science and ML techniques are increasingly seen as fundamental to drive this growth. While data science technologies like predictive analytics continue to drive innovation across enterprises, ML techniques are instrumental to scaling data science for businesses. Our contributions in that area were on plan optimization for example since 2005, e.g., on a chapter on Nourani (2018). The interplay between Decision Optimization and ML is best appreciated when one understands how each technique complements the other. ML models bring the ability to provide accurate forecasts, predictions, etc., by considering real-time inputs as well as historical data. While a reliable forecast is invaluable, having the ability to make analytics-driven decisions around the best course of action to take, e.g., IBM Watson Studio.

5.9.3 RELEVANT WORLDS AND KNOWLEDGE REPRESENTATION (KR)

Instead of using as a semantical basis for a theory, some pure mathematical structure like the Herbrand universe, Kripke structures, etc., we apply the method of generic model diagrams. We are interested in a semantical foundation of our methods and approaches, which is based on the real world consisting of people, robots, languages, and, words, etc. The usual Tarskian semantics allows us to use some symbols for denoting objects of the real world, to draw some inferences on those symbols, and to obtain some statements that will then be true in the real world. Clearly, this is the basis for the symbolic computation paradigm of AI.

It is possible, as we show by this paper (e.g., Nourani, 1992–2005), to define new symbolic computation paradigms for KR and AI reasoning based on Generic diagrams, that have appealing computing properties. Hence, usually during modeling, we focus only on some subparts of the real world, using only problem-relevant statements. What we do not know on a generalized diagram is defined in terms of a generalized Skolem function. We like to call such a restriction of the real world the Relevant World. Clearly, even such a restricted AI world may in some cases be still complex and infinite. However, by such a restriction, we have already made the number of possible interpretations, and thus the semantics of a formalization considerably smaller.

An AI world consists of individuals, functions on them, and relations between them. These entities allow us to fix the semantics of a language for representing theories about AI worlds. We take the usual model-theoretical route, and assign via an interpretation function individuals to constants, functions to function symbols, and relations to predicate symbols.

Let us define a simple language L = <{tweedy},{a},{bird}, predicate letters, and FOL.

A model may consist of:

{bird(tweedy), -penguin(tweety) → bird(tweedy), bird(tweety) v ¬ bird (tweedy)}, others may consist of {p(a), ¬p(a) → p(a), p(a) v p(x), p(a) v p(x) v p(y).}.

Because we can apply arbitrary interpretation functions for mapping language constructs into AI worlds, the number of models for a language is infinite. Although this makes perfect sense from a theoretical and logical point of view, from a practical point of view, this notion of model is too general for AI applications. Since for AI, we want models that could be computed effectively and efficiently. Thus, it is useful to restrict the types of models that we define for real-world applications. Primarily, we are interested in models with computable properties definable from the theory.

Proofs can be abstracted by generalizing away from constants in the proof. Thus, such a generalized proof can be defined by a whole class of minimal diagrams. This process is usually realized via partial deduction, which in hind-sight can be regarded as the proof-theoretical way of completing diagrams whose literals are necessary conditions for the proof. We want to present a formal relation between partial deduction from model-theoretical point of view. However, it was not clear how PD can be given a model-theoretical semantics and how knowledge is to be represented to a proof system. This was done in Nourani (2014).

This is one reason why the formulation of nonmonotonic reasoning with generic diagrams presented by this author since 2001 could be applicable here. Classes, then defining a free structure on the equivalence classes. The reasoning enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. This authors techniques since 1990 for model building was applied to the problem of AI reasoning allows us to build and extend models through diagrams. This requires us to define the notion of generalized diagram. The diagrams are used to build models with a minimal family of generalized Skolem functions. The minimal sets of function symbols are those with which a model can be built inductively. We focus our attention on such models, since they are initial (ADJ, 1973) and computable (Nouranii, 1983, 1992, 1995). The Generic diagram methods applied and further developed here, allows us to formulate AI world descriptions, theories, and models in a minimal computable manner. It further allows us to view the world from only the relevant functions. Thus models and proofs for AI problems can be characterized by models computable by a set of functions.

5.9.4 MODEL DIAGRAMS AND PARTIAL DEDUCTIONS

Proofs can be abstracted by generalizing away from constants in the proof. Thus, such a generalized proof can be defined by a whole class of minimal diagrams. This process is usually realized via partial deduction, that in hindsight can be regarded as the proof-theoretical way of completing diagrams whose literals are necessary conditions for the proof. Symbolic computation is called an unfolding, if it substitutes according teases. Under certain restrictions partial By the definition of a diagram they are a set of atomic and negated atomic sentences. Thus the diagram might be considered as a basis for a model, provided we can by algebraic extension, define the truth value of arbitrary formulas instantiated with arbitrary terms. Thus all compound sentences build out of atomic sentences then could be assigned a truth value, handing over a model. It will be made clearer in the following subsections. The following examples would run throughout the paper. Consider the primitive first order language (FOL):

$$L = \{c\},\{f(X)\},\{p(X),q(X)\}$$

Let us apply Prolog notation convention for constants and variables) and the simple theory {for all X: p(X) → q(X),p(c)}, and indicate what is meant by the various notions.

[model] = {p(c),q(c),q(f(c)),q(f(f(c))).},{p(c) ∧q(c), p(c) ∧ p(X), p(c) &p(f(X)).}, {p(c) v p(X), p(c) v p(f(X)), p(c) → ¬p(c).}
[diagram] = {p(c),q(c),p(c),q(f(c)),q(f(f(c))).}.,q(X)}, i.e., diagram = the set of atomic formulas of a model.

Thus the diagram is [diagram]= {p(c),q(c),q(f(c)),q(f(f(c))).,q(X)}

Based on the above, we can define generalized diagrams. The term generalized is applied to indicate that such diagrams are defined by algebraic extension from basic terms and constants of a language. The fully defined diagrams make use of only a minimal set of functions. Generalized diagram is [generalized diagram] = {p(c),q(c),p(f(t)),q(f(t))} for t defined by induction, as {t0 = c, and tn = {f(t(n–1))} for n>0.

It is thus not necessary to redefine all f(X)'s since they are instantiated. Nondeterministic diagrams are those in which some formulas are assigned an indeterminate symbol, neither true nor false, that can be arbitrarily assigned in due time.

[nondeterministic diagram] = {p(c),q(c),p(f(t)),
q(f(c)),q(f(f(c))),I_q(f(s)))}

t is as defined by induction before and I_q(f(s)) = I_q for some indeterminate symbol I_q, for {s = t n, n> = 2. These Generic diagrams are applicable for KR in planning with incomplete knowledge with backtracking based on a belief function that is defined from a degree of plausibility assigned to each formula on the diagrams. These were applied by Nourani (1992) to represent plausible knowledge for planning applications. A generalized free diagram (GF-diagram) is a diagram that is defined by algebraic extension form a minimal set of function symbols [generalized free diagram] = {p(c),q(c),p(f(t)),q(f(t)), q_F.s(s)} for t and s as before. A generalized free plausible diagram, is a GFD that has plausibility degrees assigned to it. These Generic diagrams are applied for KR to planning with free proof trees (e.g., Nourani, 2005).

5.9.5 DEEP KNOWLEDGE DIGITIZATION ON INCOMPLETE BASES

Existential quantified diagrams carry one main deficit. The Skolem objects are not characterized, Hilbert's epsilon symbol helps resolve this since we can apply the Hilbert epsilon encoding at FOL to have the description of the necessarily existing objects for making a proof succeed, it also allows us to characterize those objects. In Nourani (2005, 2014) the issues are dealt with for free proof trees, e.g., a blocks world problems solver is defined there. In this section, we extend the notion of generalized diagram (Generic diagram) to include plausibility and nondeterminism for planning and for representation of possible worlds. An extended notion of Generic diagram can encode possible worlds to capture the "maximally complete" idea and can be used for model revision and reconstruction.

By assigning a plausibility ranking to formulas one can set a truth limit ordinal t as the truth threshold. These notions of diagram are applied., by way of example, to planning such that the notions of computations with diagrams and free proof trees can be illustrated. A nondeterministic diagram is a diagram with indeterminate symbols instead of truth values for certain formulas. For example, [nondeterministic diagram] = {p(c),q(c),p(f(t)),q(f(c)),q(f(f(c))),I_q(f(s)))}, t is as defined by induction before and I_q(f(s)) = I_q for some indeterminate symbol I_q, for {s = t sub n, n> = 2}. p and q are language predicate letters and l_q is a variable letter designated by the index letter q to indicate Boolean model assignments, e.g., {T,F} only.

Formulas with plausibility ranking less than t would be assigned 'T' and the other formulae would be assigned 'F.' Thus, Nourani (1991,1994) defined the notion of a plausible diagram, which can be constructed to define plausible models for revised theories. In practice, one may envision planning with plausible diagrams such that certain propositions are deliberately left indeterminate to allow flexibility in planning. In Nourani (1992) nondeterministic diagrams were defined by assigning an undefined "X" symbol to predicates in the diagram whose truth values are not known at each stage of planning. Such extensions to the usual notion of diagram in model theory was one method of avoiding the computational complexity and computability problems of having complete diagrams. Truth maintenance and model revision can all be done by a simple reassignment to the diagram. The canonical model of the world is defined directly from the diagram.

5.9.6 GENERALIZED FREE SKOLEM DIAGRAMS

Such diagrams are defined by assigning truth values to predicates with known truth values at each stage and generalized Skolem functions to represent those predicates whose truth values are not known. Thus we define diagrams in which predicates are replaced by their corresponding Skolem functions. For example, in a block's world example of AI, the entry in the diagram function for top(A,B) predicate is replaced by a Skolem function F_top(A,B). We refer to such diagrams as GF-Diagrams. The example from the model of sections above is as follows. [free Skolemized diagram] = {p(c),q(c),p(f(t)),q (f(c)),q(f(f(c))),q_F.s(s)}, where t and s are as defined in the sections before. In the present paper, we devise new methods of achieving nondeterminism by proposing what we shall refer to as Free Skolemized Diagrams (Nourani, 1991,1997). Note that the GF-diagrams, as in the approach by Nourani (1992), also includes all the information required to define possible worlds. Absolute formulae can be assigned a plausibility ranking which represents their truth value through the belief function limit ordinal. Relativized truth is captured by altering the truth limit ordinal, and by leaving plausibility degrees free by an assigning generalized Skolem functions for the unknown predicates.

5.9.7 PREDICTIVE DIAGRAMS FOR KNOWLEDGE DIGITIZATION

Existentially quantified diagrams fall short on Skolemization. The Skolemized formulas are not characterized. Hilbert's epsilon symbol may be applied to solve this problem. These issues are dealt with Nourani (1995, 2003). Here we present the notion of a predictive diagram and apply it for KR to provide a model-theoretic characterization for PD and related proof trees. A predictive diagram for a theory T is a diagram D[M], where M is a model for T, and for any formula q in M, either the function f: q → {0,1} is defined, or there exists a formula p in D[M], such that T U {p} proves q; or that T proves q by minimal prediction. A generalized predictive diagram, is a predictive diagram with D[M] defined from a minimal set of functions.

A predictive diagram could be minimally represented by a set of functions {f1.,fn} that inductively define the model. The free trees (Nourani, 1995), defined by the notion of provability implied by definition, could consist of some extra Skolem functions {g1.,gl}, that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize partial deduction with free trees. Partial deduction can be regarded as a form of predictive reasoning, and vice versa, if differences in the underlying languages of PD and abduction are resolved Hoppe (1992). However, the most interesting aspect of Hoppe (1992) is that predictive reasoning can be extended to perform partial deduction, if universal quantified hypotheses are used. It is when a special consistency checking scheme, based on Hilbert's epsilon symbol (Hoppe, 1992; Nourani-Hoppe, 1994) might be used.

These extensions of PD to a predictive, nonmonotonic reasoning approach allow us to link them with the semantical approach to nonmonotonic reasoning, e.g., Nourani (1984), ECAI. By viewing PD from predictive diagrams we could define models for PD from predictive diagrams-thus a model-theoretic formulation for PD emerges (Nourani, 1995). We then define Hilbert models to handle the proof-model problems, e.g., Nourani

(2005). To culminate model discovery, we state and prove a theorem on predictive diagrams. For planning and learning the robot's mind state can be defined by a diagram grid. The starting space applicable project were meant for autonomous robots wandering at outer space, e.g., Nourani (1999, 2002). The designs are ways for a robot to update its mind state based on what it encountered on its path. What the robot believes can be defined on a diagram grid. The degree to which a robot believes something is on the grid. It can get strengthened or weakened as a function of what the robot learns as progress is brought on. Robot's Mind State-The array grid entries are pointing to things to remember and the degree to the robot believes them. Entry 15 is an item robot believes the most.

```
 ________________________________
|  3,  4,  2,  3,  11,  15,  0, ……
|
|
|
 __________________________________
```

Logically and theoretically, the grid is minimally defined by the Generic diagram functions. The gird model is a way to encode diagrammatic reasoning (Glasgow-Nayaran, 1995). We have applied predictive diagrams since 1994 to partial deduction and cumulative defaults. A predictive diagram (Nourani, 1995) for a theory T is a diagram D[M], where M is a model for T, and for any formula q in M, either the function f: q → {0,1} is defined, or there exists a formula p in D[M], such that T U {p} proves q; or that T proves q by minimal prediction.

5.9.8 PREDICTION AND DISCOVERY

Minimal prediction is an AI technique defined since the authors model-theoretic planning project. It is a cumulative nonmonotonic approximation (Nourani, 1999c) attained with completing model diagrams on what might be true in a model or knowledge base. A predictive diagram for a theory T is a diagram D (M), where M is a model for T, and for any formula q in M, either the function f: q → 0,1 is defined, or there exists a formula p in D(M), such that T ∪ p proves q; or that T proves q by minimal prediction. A generalized predictive diagram, is a predictive diagram with D (M) defined from a minimal set of functions. The predictive diagram could be minimally represented by a set of functions f1,...,fn that inductively define the model.

The free trees we had defined by the notion of provability implied by the definition, could consist of some extra Skolem functions g1.,gl that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize partial deduction with free trees. The predictive diagrams are applied to discover models to the intelligent game trees. Prediction is applied to plan goal satisfiability and can be combined with plausibility (Nourani, 1991) probabilities, and fuzzy logic to obtain, for example, confidence intervals. Let us see what predictive diagrams do for knowledge discovery KM. Diagrams allow us to model-theoretically characterize incomplete KR. To key into the incomplete knowledge base. Generalized predictive diagrams whereby specified diagram functions a search engine can select onto localized data fields.

A Generalized Predictive Diagram, is a predictive diagram with D (M) defined from a minimal set of functions. The predictive diagram could be minimally represented by a set of functions f1.,fn that inductively define the model. The functions are keyed onto the inference and knowledge base to select via the areas keyed to, designated as Sis in Figure 5.4. Visual object views to active databases might be designed with the above. The trees defined by the notion of provability implied by the definition might consist of some extra Skolem functions g1.,gn, that appear at free trees. The f terms and g terms, tree congruences, and predictive diagrams then characterize deduction with virtual trees as intelligent predictive interfaces.

Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. We have presented planning techniques, which can be applied to implement discovery planning. In planning with Generic diagrams that part of the plan that involves free Skolemized trees is carried along with the proof tree for a plan goal. The idea is that if the free proof tree is constructed, then the plan has a model in which the goals are satisfied.

The model is the initial model of the AI world for which the free Skolemized trees were constructed. Partial deductions in this approach correspond to proof trees that have free Skolemized trees in their representation. While doing proofs with free Skolemized trees we are facing proofs of the form p(g(.)) proves p(f(g(.)) and generalizations to p(f(x)) proves for all x, p(f(x)). Thus the free proofs are in some sense an abstract counterpart of the SLD. Logically and theoretically, the grid is minimally defined by the Generic diagram functions. The gird model is a way to encode diagrammatic reasoning. We have applied predictive diagrams since 1994 to partial deduction and cumulative defaults. A predictive diagram (Nourani, 1995, 2005) for a theory T is a diagram D[M], where M is a model for T, and for any formula q in M, either the function f: q → 0,1 is defined, or there exists a formula p in D[M], such that T ∪ p proves q; or that T proves q by minimal prediction.

5.9.9 DISCOVERY AS PLAN PROOF TREES

Data discovery from KR on diagrams might be viewed as satisfying a goal by getting at relevant data which instantiates a goal. The goal formula states what relevant data is sought. There are some techniques that are made use of in some recent AI literature (Hoppe, 1992) which advocate the notion of partial deduction. We propose methods that can be applied to planning with GF-diagrams such that similar effects to partial deductions can be achieved, and perhaps some of the techniques can be applied to implement discovery planning.

In planning with GF-diagrams that part of the plan that involves free Skolemized trees is carried along with the proof tree for a plan goal. The idea is that if the free proof tree is constructed, then the plan has a model in which the goals are satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed. Partial deductions in this approach correspond to proof trees that have free Skolemized trees in their representation. The use of nondeterminism by GF-diagrams is useful in knowledge discovery since there usually are many indeterminate formulas in the world diagram, whose actual values are inconsequential in an immediate plan of action, thus may be assigned a free Skolem function to satisfy a goal.

5.9.10 GF, DISCOVERY, AND PROOF ABSTRACTION

The discovery planning process at each stage can make use of GF-diagrams by taking the free interpretation, as tree-rewrite computations as in Nourani (1996), for example, of the possible proof trees that correspond to each goal satisfiability. There are several ways in which such planning can be achieved. The method that is proposed here is to make use of the free Skolemized proof trees in representing plans in terms of generalized Skolem functions. Planning with GF-diagrams carries along that part of the plan that involves free Skolemized trees, with the proof tree for a plan goal. The idea is that if the free proof tree is constructed, then the plan has a model in which the goals are satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed. Partial deductions in this approach correspond to proof trees that have free Skolemized trees in their representation.

Perhaps there is an analogy that can bring the applications of the present formulations to the AI trends closer at hand. We could view, on the one hand, SLD resolution type proofs on ground terms, where we go from p(0) to p(f(c)); or form p(f(c)) to p(f(g(c)). Whereas, while doing proofs with free Skolemized trees we are facing proofs of the form p(g(.)) proves p(f(g(.)) and generalizations to p(f(x)) proves For all x, p(f(x)). Thus the free proofs are in some sense an abstract counterpart of the SLD proofs, in the sense of the trends they have appeared in the recent AI literature, for example, Mosetic and Holsbaur (1991); Nourani (2014). These projects will be treated by our subsequent publications. Of course, this author's publications were also concerned with domain abstraction and program proof abstraction (e.g., Nourani, 1995, 1998), while proofs were by tree rewriting. A free proof tree is a proof tree that is constructed with free Skolem functions and GFS from a GF-diagram. The idea is that if the free proof tree is constructed for a goal formula, then from the GF-diagram there is a model satisfying the goal formula satisfied. The model is the initial model of the AI world for which the free Skolemized trees were constructed.

- **Theorem 5.4:** For the free proof trees defined for a goal formula from the GF-diagram there is an initial model satisfying the goal formulas. It is the initial model definable by the GF-diagram.
- **Proof:** In planning with GF-diagrams plan trees involving free Skolemized trees is carried along with the proof tree for a plan goal. The idea is that if the free proof tree is constructed, then the plan has a model in which the goals are satisfied. There is an analogy to SLD proofs. We can view on the one hand, SLD resolution type proofs on ground terms, where we go from p(0) to p(f(c)); or form p(f(c)) to p(f(g(c)). Whereas, while doing proofs with free Skolemized trees we are facing proofs of the form p(g(.)) proves p(f(g(.)) and generalizations to p(f(x)) proves For all x, p(f(x)). Since the proof trees are either proving plan goals for formulas defined on the GF-diagram, or are computing with Skolem functions defining the GF-diagram, by Definitions 5.3, 5.4, and Theorem 5.1, the model defined by the GF-diagram applies and it is initial for the proofs.

5.10 COMPETITIVE MODELS AND DIGITIZATION ECONOMIES

Predictive planning is based on goal satisfaction at models. The author has examined random sets in the AA Press volume chapter (Nourani, 2018) preceding by a brief at a mathematical logic presentation 2016, as a basis to carry structures modeling as a competitive culmination problem where models "compete" based on modeling game trees, where the model rank is higher when on game trees with a higher game tree degree, satisfies goals, hence realizing specific models where the plan goals are satisfied. For example, if there is a goal to put a spacecraft at a specific planet's orbit, there might be competing agents with alternate micro-plans to accomplish the goal. While the galaxy model is the same, the specific virtual worlds where a plan is carried out to accomplish a real goal at the galaxy via agents are not. Therefore, Plan goal selections and objectives are facilitated with competitive agent learning. The game trees are ways to encode plans with agents and compare models on goal satisfaction to examine and predict via model diagrams why one plan is better than another. Newer application are at Nourani-Schulte (2013, 2014). The interplay between Decision Optimization and ML is best appreciated when one understands how each technique complements the other.

ML models bring the ability to provide accurate forecasts (demand forecasts, equipment failure predictions, etc.), by considering real-time inputs as well as historical data. While a reliable forecast is invaluable, having the ability to make analytics-driven decisions around the best course of action to take is priceless. This can be accomplished by feeding the forecasts generated by machine-learning models as inputs to a Decision Optimization model that can then consider the various trade-offs and constraints to recommend the optimal solution to meet business goals. On the other hand, once an optimization model has recommended an action plan and that plan is in operation, the data on the execution of that plan can be used by machine-learning models to improve forecasts, to automatically make the decision models more accurate, and to hedge against risks.

When operational and cultural issues have dominated recent transformations, strategy will play a much larger role in the future. Companies are starting to move beyond operational improvement toward building decisive and enduring competitive advantage. With industries in flux, digital becoming ubiquitous, AI capable of reaching scale, and the gap between leaders and laggards widening, the time is ripe for this leap. For example, referring to "AI in business gets real," MIT Sloan Management Review article, September 2018). Companies that make the leap will achieve "digital supremacy," a quantum jump in capability that threatens the existence of competitors. Digital ledgers and crypto-economics are application areas.

Microeconomic consequences of digitalization on competitiveness (Digitalization and Clusters), Economic policy and framework for digitally transformed economies, Implications of digital markets. The development of workforce and working conditions in an increasingly digitized environment, Data Economics and Digital Value Creation, Transformation from industrial to digitally transformed economies, Influence of new information and communication technologies on market structures, studied from the perspective of industrial economics (productivity, customer behavior, power of suppliers, market-entry, etc.), digitalization, and International Development.

5.11 CONCLUDING COMMENTS

This paper presents novel techniques while exploring the distinctive characteristics of surface vs. deep digitization analytics. A novel sequent visual tableaux analytics computation system with a specific mathematical basis for designing forecasting visual analytics was previewed. AI analytics techniques including nonmonotonic predictive model diagrams for digitization analytics are new techniques that are applied with visual algebraic agent structure morphic sequences that are predictively explainable, rather than being surprise glimpses. Newer mathematical foundations are developed for the computing science that can forward visual agent computing predictive analytics, with applications to interactive predictive analytics. Applications to explaining interactive visual analytics are presented with specific examples from the enterprise modeling industry.

Data filtering with keyed functions are novel techniques for the visual surface to deep digitization (e.g., Nourani, 2013, 2018a), while rapid content processing and content delivery are alternate surface digitization functionality realized. Newer examples from industry goals for the innovations areas, for example, interactive analytics or digitization for rapid business automation or enterprise cloud or web interface processing are examined. The Generic diagram techniques are a way to encode models, e.g., BMs that with function keys to data bases-ordinary or visual, many orders of magnitude diminish the formula complexity, treating bigdata as matrices with undermined assignments to data propositions, Model checking is simplified to the same degree. Model discovery is yet another area where knowledge can be keyed to KB and applied to knowledge discovery. Knowledgebase ML completions with respect to business goals provable with our techniques in the techniques are promising new analytics for predictive BM and content processing.

KEYWORDS

- **agent interactive visual computing**
- **analytic tableaux**
- **content and proof abstraction**
- **deep vs. surface digitization**
- **enterprise web interfaces**
- **explanations and learning**
- **ISL algebras**
- **model completion**
- **model descriptions**
- **model discovery**
- **morph Gentzen**
- **morph Gentzen compact sequences**
- **neuromorphic cognition**
- **nonmonotonic reasoning**
- **predictive analytics**
- **predictive model diagrams**
- **predictive models**
- **virtual tree planning**
- **visualizing explanations**

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CHAPTER 6

EFFECT OF DIGITIZATION ON BUSINESS MODEL INNOVATION

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ABSTRACT

Industrial businesses are going through digital disruptions, and managers are under tremendous pressure to engage in digitization initiatives across the organization. Though technologies are changing and advancing rapidly, existing companies can in many cases not change their businesses fast enough. One factor that affects the pace with which firms change is a clear understanding of how to utilize new technologies for creating and delivering business values.

The purpose of this paper is to extend the body of knowledge about digital transformation and its effect on business models (BMs). Based on an empirical study as well as a literature review, digitalization is discussed in regard to its impact on BM innovation. The impacts are illustrated through several business use cases. The theoretical contributions are two: first, complementing existing studies and connect digitalization with BM innovation and second, extend the existing body of knowledge related to BM innovation and how digitalization is impacting BMs. This paper highlights the impact of advanced technologies on existing and new businesses and how companies are attracting new customers by innovating their BMs. This can help existing and new companies to look into their businesses differently. Therefore, this chapter contributes to both theory and practice to the field of BM innovation.

6.1 INTRODUCTION

Industrial businesses are going through digital disruptions, and managers are under tremendous pressure to engage in digitization initiatives across the organization. The emerging technologies such as artificial intelligence and machine learning (AI/ML), internet-of-things (IoT), industrial internet of things (IIoT), Industry 4.0, and Blockchain are disrupting businesses (Lee et al., 2019; Ibarra et al., 2017; Morkunas et al., 2019). Digitization is not only changing current businesses, but new businesses are emerging due to the advancement of technologies (Buck and Eder, 2018). Though technologies are changing and advancing rapidly, existing companies can in many cases not change their businesses fast enough, due to path dependencies. This could lead to serious negative outcomes (Lucas and Goh, 2009; McNish and Silcoff, 2015). One factor that affects the pace with which firms' change is a clear understanding of how to utilize new technologies for creating and delivering business values (Bender et al., 2018). The role of digitization and its impact on a firm's business strategy is in many cases not clear and commonly a firm views its information technology (IT)/digitization strategy as a functional level strategy (Bharadwaj et al., 2013). Thus, there should be a close link between digitization and business models (BMs) and how new BMs are evolving. However, more discussions are required to unpack this relationship (Bedner et al., 2018). The purpose of this chapter is to extend the body of knowledge about digitalization and its effect on BM innovation based on an empirical study supported by a literature review. Digitalization will here be viewed through an emerging technology lens, and based on the empirical study as well as the literature review, be discussed in regard to its impact on BM innovation. The impact will be illustrated through several business use cases.

The paper is organized as follows: first, the theoretical backgrounds of BM innovation and advanced technologies are presented. Then the research methodology is unfolded, followed by case studies, and finally, discussion and conclusions are presented.

6.2 THEORETICAL BACKGROUND

6.2.1 DIGITIZATION, DIGITALIZATION, AND DIGITAL TRANSFORMATION

Though digitization and digitalization have been used interchangeably, we define digitization as: 'transforming analog information to digital information.' Businesses have been digitizing their processes for decades. In regard to digitalization, it is the use of digital technology to develop new BMs for the enterprise and thereby to provide revenue and value producing opportunities (Ghosh, 2019). Digitization illustrates the process of the conversion (Brennen et al., 2016), digitalization refers to any changes in the organization or organization's BMs by leveraging digital technologies (Westerman et al., 2011). Muro, Liu, Whiton, and Kulkarni (2017) define digitalization as: "the process of applying digital technologies and information to transform business operations" (pp.5). Digitization can be for a particular business process or a group of processes (mostly in silos), digitalization is more intra-organizations/enterprise wide. Finally, digital transformation is the continuous interconnections of the business ecosystems including partners, suppliers, and other participants (Bloching et al., 2015). Digital transformation affects all parts of the company and it leads to the development of new BMs (Verhoef et al., 2019). Therefore, digitalization is not digital transformation, and an organization might pursue multiple digitization and digitalization projects across various sites, manufacturing facilities, and service centers. Further, digital transformation is a customer-driven strategic business transformation initiative that requires a holistic approach and a new way of doing business, by utilizing digital technologies (Ghosh, 2019).

The factors which are accelerating digitalization and digital transformation activities across different industries could be attributed to Industry 4.0/ Industrial Internet initiatives by leveraging IoT/IIoT and other emerging technologies. 'Industrial internet' is a term coined by general electric (GE) (Leber, 2012). Industrial internet combines the internet with the physical world, including factories, machines, and infrastructure and brings enormous opportunities and transforms businesses (WEF, 2017). The term 'Industry 4.0.' was proposed by German businesses and industries (Luenendenk, 2017). Industrial businesses have gone through a successive revolution, starting with mechanization (first industrial revolution), to use of electrical energy and division of labor (second industrial revolution), to machine-to-machine communication and digitalization across the organization (third industrial revolution). Lately, the focus has been on advanced digitalization and integration with horizontal organization systems and with vertical partner ecosystems (fourth industrial revolution or Industry 4.0) (Lasi et al., 2014).

These reforms have led to 'anything-as-a-service' BMs, including different business networks and partner's-based value delivery models (Rachinger et al., 2019). More and more companies are therefore moving away from product-centric models to an 'outcome-centric model,' which is known as servitization (Baines et al., 2014). To implement this model, a firm needs to redesign its businesses for distinctive value creation and value delivery for its customers and partners (Ghosh, 2019). Linz, Zimmermann, and Muller-Stewens (2017) suggest that a company is innovating its BM by digitalization and servitization and it is a competitive advantage for the company.

6.2.2 BUSINESS MODEL (BM) INNOVATION

Stewart et al. (2000) and Porter (2001) focused on the revenue models as the key component of a BM, whereas Amit, Zott, and Massa (2011) expanded the definition and found some common themes across BM scholars: (a) it emerges as a unit of analysis; (b) it is a systematic and holistic approach to explain how a firm is doing business; (c) a firm's activities defining its BM; and (d) it explains how value is created, not just how the value is captured. A BM is defined as the business logic and processes to create and capture values for the customers and the company (Bouwman et al., 2018). Teece (2018) suggests that BM is the architecture for how a company creates and delivers values to its customers and the mechanism it deploys to capture the value. Ritter and Lettl (2018) describe the BM as a concept for a company to explain "what it does," "what it offers" and "how the offer is made." Though scholars have some agreement about three basic components of a BM: value creation, value delivery and value capture (Teece, 2010), there is some confusion about BM and BM innovation (Foss and Saebi, 2017). According to Foss and Saebi (2017), BM and BM innovation are related, BM innovation includes additional innovation on top of BM and explains the drivers, facilitators, and hindrances for developing newer BMs. Further, they define BM innovation as "designed, novel, non-trivial changes to the key elements of a firm's BM and/or the architecture linking these elements" (pp.201).

BM innovation is a systematic approach for a company and it is defined as: "a change in a firm's BM that is new to the firm, and it leads to substantial changes in the practices of the firm in dealing with customers and partners" (Bouwman et al., 2018: p. 105). Digitalization has a profound impact on BM innovation. Hui (2014) highlights the importance of the new digital BM for connected ecosystem using IIoT and other emerging technologies. Table 6.1 details the value creation and capture analysis of the traditional business and connected business using IIoT (Ghosh, 2019).

TABLE 6.1 Value Creation/Capture Analysis

Value Models	Factors for Value Creation/Capture	Traditional Business Capabilities	IIoT Business Capabilities
Value creation	Customer needs	To solve existing problems (reactive).	To address the current and future needs proactively.
	Offerings	To market products with service contracts.	To market products as-a-service.
	Role of data	To maintain customers by collecting data periodically for future product enhancements.	To enhance customer satisfaction by continuous monitoring of customers.
Value capture	Path of profit	To develop and maintain sales capabilities for one-time sale of the product and service.	To enhance sales capabilities for recurring pay-per-use revenue.
	Control points	To protect using IP protection, brand values and customer support.	To protect using personalization and network effects.
	Capability development	To leverage core competencies and existing resources and capabilities.	To work with alliance partners to develop products and fill the gaps with customers.

6.2.3 ADVANCED TECHNOLOGIES AND ITS IMPACT ON BUSINESS MODEL (BM) INNOVATION

The following sub-chapter describes the impact of advanced technologies on BM innovation. First, we explain the impact of AI/ML on BM innovation, then we illustrate the impact of IoT/IIoT on BM innovation, and finally we discuss the impact of Blockchain on BM innovation. In each section, we illustrate the impact of the emerging technologies on BM innovation with the help of case studies.

6.2.3.1 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING (AI/ML)

Artificial intelligence (AI) is one of the transformational technologies which is disrupting firms. “AI refers to computer systems that thinks and acts like humans and thinks and acts rationally” (Russel and Norvig, 2009). Machine learning (ML) is a branch of AI, and can be defined broadly as a computational method that uses experience to improve performance, or to make predictions (Mohri et al., 2018). AI/ML is disrupting many industries and companies as a consequence of using these technologies for innovating existing BMs, or creating new ones (Boitnott et al., 2016). Though there are different types of ML algorithms, in general, ML algorithms are classified in three categories, supervised learning, unsupervised learning and reinforced learning/deep learning (DL) (Heidenreich, 2018). The supervised learning is the most common form of ML algorithm, which is designed to learn by examples (Wilson et al., 2019).

In supervised learning, the algorithm receives a set of inputs and a set of outputs and the goal of the algorithm is to learn to predict the output(s) from the set of input(s). The output could be a class label (classification) or a real number (regression) (Ghahramani, 2003). Linear regression algorithm is a supervised learning method which is used in predicting, forecasting, and figuring out relationship in numerical data. This is one of the earliest technique to find the relationship between two variables (Talabis et al., 2015). Classification is another category of supervised learning where the goal is to predict the classes (labels such as discrete, unordered, group membership, etc.), of new instances from past observations (Roman, 2018). The common business use cases for supervised learning are in different business areas, such as marketing and sales (customer churn rate, lifetime value of a customer, sentiment analysis, product recommendations), human resource planning (sales performance, retention, human resource allocation), security (spam filtering, detecting malicious emails and links, fraud detection), asset maintenance and IoT (supply chain and logistics planning, outage predictions, proactive asset maintenance) and entertainment (face recognition, visual alterations, turning pictures into artwork style images). In classification technique, we need labeled data (labels, label pairs) to train the classification algorithm, and most often labeled data in business may require more expenditure, and labeling data by people is time consuming and sometimes error prone. So, a new type of classification technique was developed, semi-supervised learning, where we deal with labeled and unlabeled data and the algorithm develops classifiers from the data. Due to less human intervention, it is more accurate and less time consuming (Zhu, 2005). The business use cases for semi-supervised learnings are speech recognition, internet content classification, protein sequence classification, etc.

In unsupervised learning, the algorithm only receives inputs and it does not receive any outputs or rewards from its environment. The purpose is to develop pattern(s) based on the input data (Ghahramani, 2003). The common types are clustering and association. The examples of unsupervised learning include recommender systems (Netflix can recommend a movie to its audience), and buying habits (Amazon can recommend a product to a customer). One of the primary goals of an AI system is to develop autonomous agents who interact with their environments and learn optimal behavior, which can be improved over time (Arulkumaran et al., 2017). A mathematical framework for experienced driven autonomous learning is reinforcement learning (RL) (Sutton et al., 2018). Training the model to control autonomous vehicles is a good example of RL. In industrial automation, RL techniques are used to build intelligence in complex systems.

Finally, DL is a type of ML algorithm where artificial neural networks, which are influenced by the human brains, can learn from a large amount of data (Marr, 2018). For example, DL algorithms are used in customer experience applications with chatbots. Computer visions and image recognitions are some of the example of DL.

AI/ML technologies are disrupting the BM as companies are expanding their product portfolios, developing new products and enhancing the capabilities of existing products.

6.2.3.2 IoT/IIoT/INDUSTRY 4.0

IoT facilitates connected devices to collect data from various sources across different locations and then to transmit the data to the cloud and finally, enable it to analyze the vast amount of data to make business decisions. Earlier it was difficult to collect and analyze such a large quantity of data economically, however, recent technological advancement and digitalization across the company have paved the way for IoT-enabled devices in different businesses. Industrial IoT (IIoT) was coined by GE (Leber, 2012). IIoT connects industrial assets and systems (machineries, plants, business systems, etc.), such that they can share real-time information for proactive and predictive decision making. Research suggest that intelligent systems will enable significant savings in the global market, and by saving 1% fuel in aviation, the travel industry can save $30B globally (in 15 years). Further, 1% fuel saving in power generation equipment can save $66B globally (in 15 years) (Evans et al., 2012). IIoT can therefore contribute significantly in value creation and value capturing across industries and can thereby accelerate BM innovation. Though the terms IoT and IIoT have been used interchangeably, there are some basic differences. Traditionally IoT is used for consumer internet of things. Table 6.2 (Jackson et al., 2015) depicts the important difference between IoT and IIoT.

TABLE 6.2 Difference between IoT and IIoT

	IoT	**IIoT**
Devices	Includes devices located in consumer or commercial settings such as offices, homes, and businesses.	Includes devices located in industrial settings such as factory floor, automation control, HVAC, energy grids, etc.
Reliability	Moderate requirements, ease of use, short product life cycles, 99.99% to 99.999%	Stringent requirements, high reliability, harsh environments, long product life cycles, 99.9999% to 99.99999%
Security	Requires identity and privacy	Requires robust security and very high privacy
Function	Functions that benefit end uses human lifestyles	Functions that support industrial assets and systems and with minimal human intervention
Availability	Moderate, occasional updates and random rebooting is possible	Very high availability and uptime. Scheduled patching is required.
Failure	Retry and replace	Resilience, fault-tolerance systems
Connection	Connects people to people or people to internet	Peer to peer and machine-to-machine (M2M)
Protocol	Most often IP reliant	Numerous protocols, standard-based or proprietary machine-based
Market	Mostly Greenfield, new device uptake is almost immediate	Mostly brownfield, new device uptake must be phased in.

Another concept, 'Industry 4.0' was developed by German businesses and industries in 2011 (Luenendonk, 2017), referring to a fourth industrial revolution. Lasi et al. (2014) observed that technological advancement has changed the business and operating models in the industry, starting from mechanical equipment (first industrial revolution), to usage of electric power (second industrial revolution), advancement in machine-to-machine communication (third industrial revolution) and finally cyber-physical systems (fourth industrial revolution). During these industrial revolutions, new BMs were innovated and businesses were transformed. Industry 4.0 has made fundamental changes in the industry, based on technological developments such as applications using AI, IoT, Data Analytics, Cloud technology, Robotics, Blockchain Technology, 3D Printing, Cryptocurrency, and more (Ustundag et al., 2018). Industry 4.0 has four design principles for digitalization which include interoperability (between machines by IoT and machine-to-machine communication), information transparency (computer system can design virtual representation of the physical machine, digital twins), technical assistance (human-AI interactions and Remote Process Automation, RPA) and decentralization (systems which can execute their tasks by themselves) (Lewis, 2016). Industry 4.0 and IIoT have significant impacts on current and future businesses and new and innovative BMs are being developed using these technologies.

6.2.3.3 BLOCKCHAIN

Satoshi Nakamoto (2008) wrote a white paper where he described peer-to-peer monetary transactions without going through any financial institutions as intermediaries. Nakamato also devised a distributed ledger for such transaction based on "chain of blocks" and later the technology was renamed as 'Blockchain' (Economist, 2015). Blockchain has introduced new BMs as intermediaries are not required, when executing any contract between parties. The concept of "Smart Contract" is a powerful technology, which can move digital assets automatically based on pre-defined rules (Buterin, 2014). So, a contract between two or multiple parties can be executed digitally and contract terms can be reinforced without human or third-party intervention. The key characteristics (Zheng et al., 2018) of Blockchain are as follows:

- **Decentralization:** In any conventional and centralized transaction system, there is an intermediary who is controlling and validating the transactions (e.g., Central Bank), adding cost to the transactions and increasing delivery times. Whereas, Blockchain works as a trusted distributed ledger and no intermediary is required. In this process, Blockchain reduces the cost and improves the performance of the transactions.
- **Persistency:** All the transactions are written into distributed ledger, and once written, the transactions are immutable and cannot be erased from the ledger. Thus, Blockchain helps in developing trusts among trading partners.
- **Transparency:** The trading partners in the Blockchain ledger can view each other's transactions based on the agreements between the parties, thus, it creates transparency and provides clear visibility of all the transactions.
- **Auditability:** All transactions are validated and written into the Blockchain with timestamps and all other details about the transactions. So, it is very easy to audit any transaction or a group of transactions.

There are four common types of Blockchain technologies such as public, private, consortium, and hybrid (Sharma, 2019). There are other variations but these four are common in industry:

- **Public Blockchain:** It is a non-restrictive, permission-less distributed ledger system and anyone with an internet connection can participate in this system and creates its own node. Once a user joins a public Blockchain, it can utilize the various facilities available to the nodes for initiating transactions. The common examples of such Blockchain are, Bitcoin, Litecoin, and Ethereum.
- **Private Blockchain:** As the name suggests, it is a restrictive, permissioned Blockchain network where private parties can join the Blockchain. Someone on the private Blockchain is the owner of the Blockchain and manages the distributed ledger for its Blockchain partners. In general, there are contracts (smart contracts) between parties and Blockchain activates the contracts once the transactions are written into the ledger. Hyperledger, Corda, Multichain are some common examples of private Blockchain.
- **Consortium Blockchain:** This is one form of private Blockchain, where the Blockchain is managed not by one organization, but by a consortium. In this type of Blockchain, only a few users have the permission to write into the distributed ledger and others can query and view the transactions. Some typical example of consortium Blockchain are Hyperledger, Corda, and Quorom.
- **Hybrid Blockchain:** It is a combination of private and public Blockchain. The nodes in the Blockchain decide who has what rights to write or view transactions in the Blockchain. Dragonchain is an example of hybrid Blockchain.

Initially, Blockchain was concentrated to Bitcoin-related transactions, but later, it is being used for different business purposes across the industry. Blockchain is creating new value propositions for the companies which were not possible earlier.

Blockchain along with IIoT and AI-ML applications are widely used in multiple industries including manufacturing (product provenance, monitoring product quality, proactive asset maintenance, etc.), retail (supplier-partner management, loyalty programs, inventory management, etc.), healthcare (clinical trials, outcome-based contracts, medicine supply chain, etc.), financial markets (cross-currency payments, trade management, fund management, etc.), and government (Asset registry, citizen identity, fraud, and compliance, etc.).

6.3 METHODOLOGY

We have chosen three case studies to illustrate how advanced technologies such as AI, ML, IoT, Big data, and Blockchain have accelerated the digital transformation. Each case description is based on unique empirical data collected by the authors while working at the respective companies and discussing the digitalization processes. However, all the information in the case studies are publicly available information and the authors validated the information by interviewing six key managers of the respective companies who are involved in digital transformation. Secondary information has been collected from business journals and company annual reports.

Three cases were chosen to illustrate the effects of digital transformation on BM innovation. The first case study is highlighting the BM innovation initiative for a large aircraft manufacturer, Rolls Royce. The company is leveraging advanced technologies such as AI, ML, IoT, big data, and analytics to transform their product centric BM to a pay per use BM. By successfully utilizing advanced technologies, the company can monitor the health of its machines on a real-time basis and manage the performance of these machines remotely. The changes in the operating models have helped the company to innovate its BM and offer pay per use service to its customers. The authors have interviewed business managers of the company to validate the case study. The second case study from GE Digital, a subsidiary of GE. In this case, GE Digital has developed Digital Twins for a company, Bently Nevada, which provides asset protection and condition monitoring services for multiple industries. To accelerate digitalization, companies are utilizing digital replica of physical machines or processes, known as Digital Twins, to simulate real-time behavior. To develop Digital Twins, the companies are collecting huge amount of data from the physical machines and processes on a real-time basis, feeding the data in a big data and Analytics platform and utilizing AI/ML algorithms to simulate actual machine and process conditions. The Digital Twins have allowed the companies to develop new products and processes faster and improve the quality of the products in production. One of the authors has worked at GE Digital and interviewed managers to validate the publicly available information. The third case is related to cargo ship management solution provider, CargoSmart, as it utilizes Oracle's Blockchain Platform and developed a Blockchain-based cargo ship management software-as-a-service (SaaS) application for its shipping customers. Blockchain technology has helped the company to developed a trusted, non-mutable, smart contract-based distributed blockchain ledger for managing shipping transactions and documents effectively. One of the author interviewed company managers and validated the information.

6.4 CASE STUDIES

6.4.1 ROLLS ROYCE: POWER BY THE HOUR

Rolls Royce aerospace business makes aircraft engines for civil, military, and corporate aircrafts. In 2019, its revenue was 16,587 million BP and the company made a profit of 1311 million BP. The company has 21% market share and its competitor GE Aviation has a 31% market share in the commercial aircraft engine (Statista, 2020). The commercial aircraft business account for around 50% of the revenue for Rolls Royce. To address price sensitive customer in the commercial aviation business, Rolls Royce introduced a new BM, "Power by the hour," which is a significant deviation from its core BM (Steiber, Alange, Ghosh, and Goncalves, 2020). Rolls Royce charges a one-time price for its aircraft engine and it signs a service contract with the customer for regular maintenance of its engine. This is a standard product centric BM for most of the equipment manufacturer.

In the innovative pay per use value-based BM, the price is based on the hourly performance of the aircraft engine, and the customer pays for the performance instead of buying the engine from Rolls Royce. Rolls Royce started their 'Total Care' BM in the mid-1990s, when the company introduced a new venture, "Total Care Term," where customers signed up for coverage over a fixed fee per engine flight hours. The fees were charged based on the expected number of shop visits and related costs divided by the expected number of flight hours. Though there were uncertainties about the engine conditions at the end of the contract, customers chose this term for the lowest cost. In 2007, Rolls Royce enhanced the existing maintenance service venture and introduced "Total Life." As the company gained more and more experience in servicing aircraft, it introduced a new service BM to increase their market share in the aircraft maintenance business. In the "Total Life" model, Rolls Royce provides aircraft maintenance for life (as long as the aircraft is in operation) and the flying hours are considered for per-hour cost; the service can be transferred to other aircraft operators in case of any changes in ownership. In 2015, Rolls Royce introduced the "Total Care Flex" BM, where a customer can pay a higher per-hour cost for flexibility. The BM 'Total Care' helps the company to reduce waste and optimize resource efficiency while it enables customers to maximize the flying hours of their aircraft.

Rolls Royce digitally transformed its business by digitalizing its own business processes and integrating its business systems with its customers systems such that they can exchange business information on a real-time basis using advanced technologies such as IIoT, AI-ML, and Big data. The company monitors the performance of the aircraft engines by implementing an IoT-based real-time data collection and analysis system and utilizing AI/ML and big data analytics technologies for proactive maintenance of the engines. Rolls Royce, in turn, has a constant revenue streams by charging by the flying hours of the engines. BM transformation such as 'Total Care' drives new business ventures as Rolls Royce can provide other value-based services to the airlines and the airports. This example illustrates how a company such as Roll Royce utilizes transformation technologies to innovate its value creation, delivery, and capture process, which in turn facilitates new business ventures.

6.4.2 GE DIGITAL TWIN

Bently Nevada is an asset protection and condition monitory hardware software and services company of Baker Hughes (A GE Company) in Minden Nevada. Its products are used by oil and gas, power generation, mining, and other industries to monitor the mechanical condition of monitoring equipment and detect the early failures of the machineries. Bentley Nevada was started in 1961 and acquired by GE Oil and Gas in 2002 and became a part of Baker Hughes in 2017. The manufacturing facility in Minden, Nevada is the main factory of the company. The scientists and researchers at GE Digital and GE Research Laboratory have worked with Bently Nevada and developed digital twins of supply chain and factory processes such that the factory can manage its supply change effectively and thus the factory can reduce supply chain costs and improves customer fulfillments. Digital twin is a digital representation of the physical world, including processes, systems or assets for greater scrutiny, analysis, and innovation (Ghosh, 2019). The concept of Digital Twin was introduced by Michael Grieves in 2003 (Grieves, 2016), however, due to the advancement of AI/ML, IoT, big data, and analytics, Digital Twins are used across many industries and situations (Grieves et al., 2017). According to Jeff Gordon, plant manager at Minden, "as any plant manager knows, the slightest disruptions in your supply chain or factory operations can alter everything from delivery and cycle times to inventory levels and factory capacity" (GE Reports, 2017). The Digital Twin has helped the plant manager to optimize their supply chain and improve factory performance. Based on these technological improvements, Bently Nevada is considering to offer performance-based machine maintenance for its customers. Digital Twin not only helps in improving operational efficiency, but it also helps in developing new product development (NPD) capability (Ghosh, 2019). Pavlou and Sway (2011) researched NPD initiatives of 180 firms and concluded that firms with strong NPD capabilities are more likely to introduce new products that better match customer needs. According to Kevin (2020), AI/ML and IoT are rewriting the possibilities of the digital twins. Earlier, collecting a huge amount of data on a real-time basis and analyzing the data was a challenge. But with technological improvements of IoT, we can collect continuous asset data from various sensors and collate that data with design data and develop a comprehensive digital twin by implementing sophisticated AI-ML algorithms.

Digital Twin has helped Bently Nevada in developing new and innovative products faster (value creation activity) and also helps in developing new performance-based maintenance service (value capture activity). Thus, Digital Twin can help a company in its BM innovation journey.

6.4.3 ORACLE AND CARGOSMART

CargoSmart is a global shipment management software solution company and it manages 40 ocean carriers to manage shipments across the globe. Though the company started in 2000 to manage global shipment, CargoSmart introduced a Blockchain-based cargo shipment management solution in 2018 (CargoSmart press release, 2018). CargoSmart's platform has been developed leveraging the Oracle Blockchain platform, which is based on Hyperledger fabric.

The shipping documentation process is complex, and it involves multiple suppliers and partners geographically distributed across multiple regions. The regulatory and compliance documentation requirements for different countries are different, and cargo shipments spend a substantial time in procuring and processing these documents at air and sea cargo terminals. According to Lionel Louie, Chief Operating Officer (COO) of CargoSmart, Oracle Blockchain-based cargo shipment management solution has revolutionized shipping. CargoSmart formed a global shipping network consortium and nine leading ocean carriers and terminal operators have signed a memorandum of understanding (MoU) to join the consortium (Hall, 2018).

Earlier, most of the shipping processes were manual and partners needed to reply on email confirmations from different points in the shipping journey. The custom clearance processes were cumbersome and error prone. The shipping containers used to wait a long time at customs due to wrong and improper documentation. The customers who were receiving the products were also not notified on time such that they could make alternate arrangements for any shipping delays. Overall, shipping processes were manual and reactive. A shipment management solution based on Blockchain and IIoT solved those problems and made the supply chain processes more proactive. The solution utilizes Blockchain Smart Contract agreements between different parties and enforces documentation processes across the whole shipment process. The companies participating in the blockchain use the blockchain ledger as the single source of truth, and make payment arrangements based on the delivery of the goods at the destination. CargoSmart's BM is based on platform-based BM. The company offers a subscription-based service for its shippers and based on the subscription level; the shippers have limited to advanced shipping management capabilities. According to Accenture report (2018), the blockchain can improve supply chain transparency across the network by 20% to 30%, reduce operating costs by 10% to 15%, increase speed of contract settlements by 15% to 25% and help in increasing revenue by 2% to 4%. Thus, by leveraging Blockchain, CargoSmart's has developed a platform-based BM which is an example of BM innovation.

6.5 DISCUSSION AND CONCLUSIONS

The analysis of the three cases will be based on the IT-Enabled business transformation framework presented in Chapter 1, Digitization's effect on value creation (p. 2). Venkatraman (1994) presented a five-level framework which includes; localized exploitation, internal integration, business process redesign, business network redesign (BNR) and finally business scope redefinition.

Business transformation initiated by the first two levels is evolutionary, or on a more incremental level, while the next three levels are revolutionary and therefore commonly are more challenging to achieve for companies, due to path dependency. This framework is a maturity model and a company move from one level to the next, based on the digital transformation efforts and competencies. BNR on level four is an enhancement of traditional business process reengineering (BPR) which improve intra- and inter-organizational processes of entire value creation networks, including internal departments and external partners (Reichmayr et al., 1999). Earlier researchers suggested that electronic data interchange (EDI) can help in BNR. However, Spinardi et al. (1996) suggest that EDI based network may not be able to change inter organizational business processes. Brynjolfsson and Mcafee (2017) suggest that AI/ML has a transformational impact on businesses more significant than other technologies as it can totally redesign the business and hence accelerate digital transformation. Digital platforms are enabling cross-boundary industry disruptions and helping in creating new business strategies and changing the scope of the business (Burgelman et al., 2007). Digitalization within different functions of a company and integrating with external partners (industry 4.0 initiatives) are defining the scope of a company's BMs and its digital business strategy. According to Bharadwaj et al. (2013), digital business strategy extends the scope beyond firm boundaries and supply chains to dynamic ecosystems that cross traditional industry boundaries and helps a company to develop new value creation and value delivery models.

In case of Roll Royce, when they started their "total care" BM, according to our assessment, the company was at level three maturity. At that time, they integrated all of their internal business processes, and the business-related structured and unstructured data was stored in a big data and analytics system. Further, the company developed new business processes for NPD, sales, marketing, and customer service. In the next phase of power-by-the-hour BM, the company moved from level three to level four, BNR, and started collecting machine health information from its customers by implementing IoT based data collection processes to collect data from aircraft engines. Also, the company integrated company's business systems with customer business systems such that Rolls Royce could receive real-time machine data from its customers from various locations. This helped the company to develop new pay-per-use BMs for the airline customers.

Similar to Roll Royce, according to our assessment, Bently Nevada reached a third level maturity before introducing digital twins in its manufacturing systems. Bently Nevada already consolidated the data across its factories and collected machine level information from its customers from weekly batch processes. Thus, they could not analyze the data on a real-time basis for effective decision making. With the help of GE Digital, Bently Nevada could collect the data from its factories and suppliers on a real-time basis and developed digital twins for its manufacturing processes and supply chain by integrating IoT data, supply chain data and logistics data from its partners. The digital twins leveraged AI-ML algorithms for machine prognostics and supply chain planning and execution. Thus, digital twins helped the company to design its business networks based on its digital transformation strategy and to create new values for its products and services.

In the case of CargoSmart, according to our assessment, the company is at the fifth level of business transformation as it has redefined its business scope and extended the new customer profiles by offering new products and services to its customer. The company has started its business in 2000, and since then it is engaged in shipping container management. However, when they developed a Blockchain and IIoT based shipping software platform, it redefined its traditional business and started a new software business (https://www.cargosmart.ai/en/). This platform-based BM allows its partners to participate in the Blockchain transactions by paying service fees, and then they can also interact with other trading partners. The consortium-based Blockchain platform helped the company to get some early customers who are interested to participate in shipping management activities. Based on the Blockchain platform and leveraging advanced technologies (AI-ML, IIoT) CargoSmart developed a suite of software solutions such as shipment visibility and predictive analysis, global shipping business network and blockchain for shipment documentation.

Based on the above, advanced technologies such as AI-ML, IIoT, and Blockchain have helped companies in their BM innovation initiatives (Table 6.3). Frank et al. (2019) argued that digital transformation started by advanced technologies helped companies to innovate their BMs into more service centric models. BM innovation also unlocked the value of advanced technologies by creating new outcomes for the existing business and helped them to redefine their businesses. However, more research work is necessary to measure the direct outcomes of advanced technologies and its effect on BM innovation.

TABLE 6.3 Difference between IoT and IIoT

	IoT	**IIoT**
Sensors/Data Collection	Normally at homes, offices, and consumer settings	Normally at industrial settings such as factories, air-conditioning equipment, Aircraft engines, wind turbines
Fault Tolerance	Very low (should be available 99.99% to 99.999%)	Extremely low (should be available 99.9999% to 99.99999%)
Authentication	Normally user-id and password	Multi-factor authentication
Software updates	Can take the system down	Must be planned and automatic updates are preferred
Recovery	Can reboot, and retry	Auto recovery, redundant systems
Connectivity	Through internet	Peer to peer and machine-to-machine (M2M)
Access mechanism	TCP/IP	TCP/IP, standard, and non-standard proprietary machine protocols
Opportunity	Mostly greenfield and new products are encouraged	Mostly brownfield, new device uptake must be phased in.

KEYWORDS

- **artificial intelligence**
- **business network redesign**
- **deep learning**
- **electronic data interchange**
- **industrial internet of things**
- **information technology**

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CHAPTER 7

AI PROCESS DESCRIPTION ALGEBRAS AND ONTOLOGY PRESERVATION TECHNIQUES

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ABSTRACT

Tree computing models with ontology preserving functions are applied to transform learning across domains with structural morphisms (first author 1992–2005). A computing model based on novel competitive learning with multiplayer game tree planning is applied where computing agents compare competing models to reach goal plans. Goals are satisfied based on competitive game tree learning. The techniques are example prototypes for modeling ontology algebras. Example Applications to data filtering, robotics processes, class hierarchical transaction morphisms, exchanges are the newest areas. Modeling frameworks are the natural applications for our event process algebras. Our techniques allow modeling learning across class ontologies and process models based on agent computing structural morphisms to model the ontology transfer processes. Applications to Formal concept description is developed with new description logic algebraic models. Novel concept description ontology algebras and concept description ontology preservation morphisms are presented. Based on that new concept ontology algebras with description ontology algebra preservation theorem are proved.

7.1 INTRODUCTION

An overview of a practical agent learning based on new competitive modeling techniques applying the IM_BID techniques (Nourani, 2005) is presented with augmentation to with standard agent modeling (Nilsson-Genesereth, 1987). A specific agent might have the internal state set I, in which the agent can distinguish its membership. The agent can transit from each internal state to another in a single step. With our multi-board model, agent actions are based on I and board observations. Transfer learning is carried on with agent morphisms. Predictive and competitive model learning is presented applying agent game trees. Ontology preservation principles are introduced for learning ontology. The preservation principles are further applied to the knowledge bases that support the transfer learning on the BID model-beliefs-intentions-desires (Brasire-Treur, 1996).

An ontology defines a common vocabulary for researchers that wish to share information in a domain. Important content is machine-interpretable definitions of basic concepts in the domain and relations among them. That allows sharing a common understanding of the structure of information among persons or computing agents. Ontology structures enable reuse of domain knowledge and make domain assumptions explicit—that allows one to separate domain knowledge from the operational knowledge. Software agents are one of the more common goals in developing ontologies (Musen, 1992; Gruber, 1993).

Competitive game tree learning is the basis for the authors' application to business and economics game modeling. Deduction models attain a new perspective with the techniques here. Context abstraction and met-contextual reasoning are introduced as a new field. Multiagent visual multi-board planning has been applied in the authors' projects to space navigation and spatial computing learning. In a Haptic computing logic (Nourani, 2005), the learning process can be seen as an emotional and personal, game-based, and proactive learning Game-based Learning, emotions, and emotional agents; henceforth, abbreviated as the BID model (Brazier-Truer et al.).

Section overviews are as follows. Section 7.2 develops the stage for the agent computing models that are applied to characterize agent computations based on standard Desire modeling augmented with newer agent module algebras. Section 7.3 presents the competitive modeling techniques with signature trees. Tree computations to realize goals for competitive models are the bases for model compatibility characterizations on realizing goals on computation trees. Generic model diagrams are applied to compare models.

Section 7.4 presents signature tree morphisms and module preservation techniques based on alternative agent computing techniques. Agent algebras and morphisms render a basis for defining ontology preservation principles.

Section 7.5 applies presents Kleene algebras in conjunction with the above sections to develop a basis for model-based concept learning with preservation morphism mappings for transfer learning across domains. Section 7.6 develops the new basis for ontology algebras on Concept Descriptions. A categorical characterization envelopes constructive description logic with concert description algebra monads on agent signature trees. Based on that new concept ontology algebras with description ontology algebra preservation theorem are presented. Applying monadic structures to description algebras ontology preservation is proved on D-algebra on free signature tree monads. The mathematics foundation for the signature trees and monads areas are presented on a volume (Nourani-Eklund, 2020).

Section 7.7 presents event description ontology, learning concepts, and ontology preservation techniques are previewed. Formal concept description ontology algebras are briefly described with specific theorems on concept description ontologies with agent signature tree computing. Categorical characterizations follow on power signature data filtering. Specific preservation theorems on concepts descriptions are briefly presented. Data filtering is previewed on a concluding section with specific examples on big data and ontological learning.

7.2 THE AGENT MODELS AND DESIRE

Let us start with the popular agent computing model, the Beliefs, Desire, and Intentions, BID is a generic agent computing model specified within the declarative compositional modeling framework for multi-agent systems, DESIRE. The model, a refinement of a generic agent model, explicitly specifies motivational attitudes and the static and dynamic relations between motivational attitudes. Desires, goals, intentions, commitments, plans, and their relations are modeled. Different notions of strong and weak agency are presented at Wooldridge and Jennings (1995). Velde and Perram (1996) distinguished big and small agents. To apply agent computing with intelligent multimedia, some specific roles and models have to be presented for agents. The BID model has emerged for a "rational agent": a rational agent described using cognitive notions such as beliefs, desires, and intentions. Beliefs, intentions, and commitments play a crucial role in determining how rational agents will act. Beliefs, capabilities, choices, and commitments are the parameters making component agents specific. A generic BID agent model in the multiagent framework DESIRE is presented towards a specific agent model (Figure 7.1).

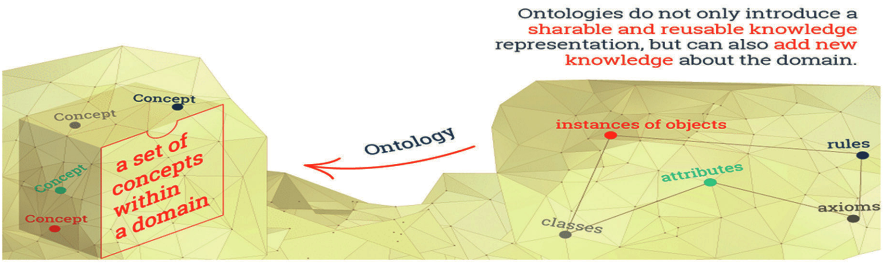

FIGURE 7.1 Ontology, concepts, and descriptions: A knowledge hub analogy.

Source: https://www.ontotext.com/knowledgehub/fundamentals/what-are-ontologies/

An ontology is a formal description of knowledge as a set of concepts within a domain and the relationships that hold between them. When one formally specifies the components such as individuals (instances of objects), classes, attributes, and relations as well as restrictions, rules, and axioms, an ontology description is realized. Towards that goal, an ontology data model can be applied to a set of individual facts to create a knowledge graph. A knowledge graph is a collection of entities, where the types and the relationships between them are expressed by nodes and edges between these nodes, thereby describing the structure of the knowledge in a domain. In contrast, other methods use formal specifications for knowledge representation (KR) such as vocabularies, taxonomies, thesauri, topic maps, and logical models. However, unlike taxonomies or relational database schemas, ontologies express relationships and enable users to link multiple concepts to other concepts in a variety of ways.

7.3 COMPETITIVE MODELS AND SIGNATURE TREES

Planning is based on goal satisfaction at models. Multiagent planning, for example, as Muller-Pischel (1994); Bazier et al. (1997), in the paper is modeled as a competitive learning problem where the agents compete on game trees as candidates to satisfy goals hence realizing specific models where the plan goals are satisfied. When a specific agent group "wins" to satisfy a goal the group has presented a model to the specific goal, presumably consistent with an intended world model. For example, if there is a goal to put a spacecraft at a specific planet's orbit, there might be competing agents with alternate micro-plans to accomplish the goal. While the galaxy model is the same, the specific virtual worlds where a plan is carried out to accomplish a real goal at the galaxy via agents are not. Therefore, Plan goal selections and objectives are facilitated with competitive agent learning. The intelligent languages (Nourani, 1993d) are ways to encode plans with agents and compare models on goal satisfaction to examine and predict via model diagrams why one plan is better than another or how it could fail.

7.3.1 INTELLIGENT AND/OR TREES AND SEARCH

AND/OR trees Nilsson (1969) are game trees defined to solve a game from a player's standpoint. Formally a node problem is said to be solved if one of the following conditions hold:

1. The node is the set of terminal nodes (primitive problem-the node has no successor);
2. The node has AND nodes as successors and the successors are solved;
3. The node has OR nodes as successors and any one of the successors is solved.

A solution to the original problem is given by the subgraph of AND/OR graph sufficient to show that the node is solved. A program which can play a theoretically perfect game would have a task like searching and AND/OR tree for a solution to a one-person problem to a two-person game. An intelligent AND/OR tree is an AND/OR tree where the tree branches are intelligent trees.

The branches compute a Boolean function via agents. The Boolean function is what might satisfy a goal formula on the tree. An intelligent AND/OR tree is solved iff the corresponding Boolean functions solve the AND/OR trees named by intelligent functions on the trees. Thus node m might be f(a1,a2,a3) and g(b1,b2), where f and g are Boolean functions of three and two variables, respectively, and ai's and bi's are Boolean valued agents satisfying goal formulas for f and g.

An intelligent AND/OR tree is solved iff the corresponding Boolean functions solve the AND/OR trees named by intelligent functions on the trees. Thus node m might be f(a1,a2,a3) and g(b1,b2), where f and g are

Boolean functions of three and two variables, respectively, and ai's and bi's are Boolean valued agents satisfying goal formulas for f and g (Figure 7.2).

```
g is on OR agent

      /|\

       |

   b1 | b2 f

    /__|__\

      /|\

f is an AND agent
```

FIGURE 7.2 Agent AND/OR trees.

Thus a tree node m might be f(a1,a2,a3) and g(b1,b2), where f and g are Boolean functions of three and two variables, respectively, and ai's and bi's are Boolean valued agents satisfying goal formulas for f and g. A tree game degree is the game state a tree is at concerning a model truth assignment, e.g., to the parameters to the Boolean functions above. Let generic diagrams or G-diagrams be diagrams definable by specific functions. Intelligent signatures (Nourani, 1996a) are signatures with designated multiplayer game tree function symbols. A soundness and completeness theorem is proved on the intelligent signature language Nourani (1999a). The techniques allowed us to present a novel model-theoretic basis to game trees, and generally to the new intelligent game trees.

7.3.2 TREES AND MODEL COMPATIBILITY

Now let us examine the definition of the situation and view it in the present formulation.

- **Definition 7.1:** A situation consists of a nonempty set D, the domain of the situation, and two mappings: g,h. g is a mapping of function letters into functions over the domain as in standard model theory. h maps each predicate letter, pn, to a function from Dn to a subset of {t,f}, to determine the truth value of atomic formulas as defined below. The logic has four truth values: the set of subsets of {t,f}. {{t},{f},{t,f},0}. the latter two is corresponding to inconsistency, and lack of knowledge of whether it is true or false.

  The above truth-value assignments indicate that the number of situations exceeds the number of possible worlds. The possible worlds being those situations with no missing information and no contradictions. From the above definitions, the mapping of terms and predicate models extend as in standard model theory. Next, a compatible set of situations is a set of situations with the same domain and the same mapping of function letters to functions. In other words, the situations in a compatible set of situations differ only on the truth conditions they assign to predicate letters.
- **Definition 7.2:** Let M be a structure for a language L, call a subset X of M a generating set for M if no proper substructure of M contains X, i.e., if Mis the closure of X U {c[M]: c is a constant symbol of L}. An assignment of constants to M is a pair <A,G>, where A is an infinite set of constant symbols in L and G: A M, such that {G[a]: a in A} is a set of generators for M. Interpreting a by g[a], every element of M is denoted by at least one closed term of L[A]. For a fixed assignment <A,G> of constants to M, the diagram of M, D<A,G>[M] is the set of basic [atomic and negated atomic] sentences of L[A] true in M. [Note that L[A] is L enriched with set A of constant symbols.]

  Generic diagrams, denoted by G-diagrams, were what we defined since the 1980's to be diagrams for models defined by a specific function set, for example,$_1$ Skolem functions.
- **Definition 7.3:** A Generic diagram for a structure M is a diagram D<A,G>, such that the G in Definition 7.2 has a proper definition by specific function symbols.
- **Remark:** The functions above are those by which a standard model could be defined by inductive definitions.
- **Theorem:** (Nourani, 1992) Two situations are compatible iff their corresponding generalized diagrams are compatible with respect to the Boolean structure of the set to which formulas are mapped (by the function h above, defining situations).

To examine compatibility on model diagrams, minimal prediction was developed around 1994. The artificial intelligence (AI) technique defined since the first author's model-theoretic planning projects, is a cumulative nonmonotonic approximation.

7.4 SIGNATURE TREE MORPHISMS AND MODULE PRESERVATION

From the software agent designer's viewpoint, however, there is modularity with artificial structures. Artificial structures (Nourani, 1997) implemented by agent morphisms. Knowledge acquisition requires either interviewing an expert, brainstorming with a group of experts, or structuring one's thoughts if the specifier is the expert. For multiagent designs, there are active learning agents and automatic learning. The author first author had presented the notion of Nondeterministic Knowledge (Design_Agents) (Nourani, 1995). Design_Agents is formulated to deal with the conceptualization stage and is being applied by the present project to define active learning by agents. Design_Agents requires the user to inform the specifier as to the domains that are to be expected, i.e., what objects there are and what the intended actions (operations) on the objects are, while fully defining such actions and operations.

The actions could be in the form of processes in a system. The relations amongst the objects and the operations (actions) can be expressed by algebras and clauses, which the specifier has to present. The usual view of multi-agent systems might convey to an innocent AI designer that an agent has a local view of the environment, interacts with others, and has generally partial beliefs (perhaps erroneous) about other agents. On the surface the Design_Agents specification techniques might appear as being rigid as to what the agents expect from other agents. The Design_Agents specification does not ask the agents to be specified up to their learning and interaction potential. Design_Agents only defines what objects might be involved and what might start off an agent. It might further define what agents are functioning together. Thus specifications are triples <O,A,R> consisting of objects, actions, and relations. Actions are operations or processes.

7.4.1 AGENTS, MODULES, AND ALGEBRAS

A formal basis for agent computing is a state-space model developed by Genersereth-Nillson (1987). There are knowledge computing models that we can apply to ontology mappings. The computing enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. The models to be defined are for complex computing phenomena, for which we define generalized diagrams. The techniques in (Nourani, 1983, 1987, 1991, 1994a) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. It required us to define the notion of generalized diagram.

Generic diagrams were designed to build models with prespecified generalized Skolem functions. The specific minimal set of function symbols is the set with which a model for a knowledge base can be defined. The G-diagram techniques allowed us to formulate AI worlds, KB's in a minimal computable manner to be applied to agent computation. The techniques in Nourani (1991, 1994a) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. A technical example of algebraic models defined from syntax had appeared in defining initial algebras for equational theories of data types (ADJ, 1973) and our research in Nilsson (1969). In such direction for computing models of equational theories of computing problems are presented by a pair (,E), where is a signature (of many sorts, for a sort set S) (ADJ, 1973; Nourani, 1995a) and E a set of -equations. Signatures are in the same sense as key signatures in music.

- **Definition 7.4:** An s-sorted signature S or operator domain is a family <w,s> of sets, f or s S and w S* (where S* is the set of all finite strings from S, including the empty string). call f <w,s> and operation symbol of rank w,s; of arity w, and of sort s.

  The figure depicts an S-sorted signature from ADJ (1973).

  We apply multi-sorted algebras via definition 2.3 to multiagent systems.
- **Definition 7.5:** Let S be an S-sorted signatures. A S-algebra A consists of a set As for each s S (called the carrier if A of sort s) and a function <A>: As1 x As2 x.xAsn As for each <w,s>, with w = s1s2.sn (called the operation named by). For <,s>, A As, i.e., the (set of names) of constants of sort s.
- **Definition 7.6:** If A and B are S algebras, a-homomorphism h:A ® B is a family of functions <hs:As Bs> s in S that preserve the operations, i.e., that satisfy (h0) For <,s>, the hs(A) = B; (h1) If, For <w,s>, with w = s1s2.sn and <a1.,an> As1 x As2 x.xAsn, then hs[A(a1.,an)]B(hs(a1).,hs(an)).

  From Nourani (1995, 1996a) we have the following notions:

- **Definition 7.7:** A signature is intelligent iff it has pre-designated property function symbols. We say that a language has intelligent syntax if the syntax is defined on an intelligent signature.
- **Remark:** Example designations are 1-1 functions symbols.

  The above definition can be further developed for arbitrary signatures to encode language structural topology.
- **Definition 7.8:** A language L is said to be an intelligent language iff L is defined from an intelligent syntax.

  A practical example of intelligent languages was presented composed from <O,A,R> triples as control structures, e.g., SERF(Nourani, 1993). The functions in AF are the agent functions capable of message passing. The O refers to the set of objects and R the relations defining the effect of A's on objects. Amongst the functions in AF, only some interact by message passing. The functions could affect objects in ways that affect the information content of a tree. There you are: the tree congruence definition thus is more complex for intelligent languages than those of ordinary syntax trees. Let us define tree information content for the present formulation. Hence there is a new frontier for a theoretical development of the <O,A,R> algebras and that of the AII theory. <O,A,R> is a pair of algebras, <Alg[A],Alg[F]>, connected by message passing and AII defines techniques for implementing such systems. To define AII we define homomorphisms on intelligent signature algebras.

  For an intelligent signature IS, let T_{IS} be the free tree word algebra of signature IS. The quotient of T_{IS} the word algebra of signature, with respect to the I-congruence relation generated by a set of -equations E, will be denoted by T<IS,E>, or T<P> for presentation Component-wise definitions for a morphism might be viewed as functions on a multi-sorted signature carrying the sextuple. Similar morphisms can be defined for knowledge level agents, which we can refer to by KL-morphisms.

  The techniques in Nourani (1991, 1994a) for model building as applied to the problem of AI reasoning allows us to build and extend models through diagrams. A technical example of algebraic models defined from syntax had appeared in defining initial algebras for equational theories of data types (ADJ, 1973) and our research in Nilsson (1969). In such direction for computing models of equational theories of computing problems are presented by a pair (Σ,E), where is a signature (of many sorts, for a sort set S) (ADJ, 1973; Nourani, 1995a) and E a set of -equations. Signatures are in the same sense as key signatures in music. The notion of an intelligent signature (Nourani, 1996) is simply a designation that there is a sub signature with specific properties, for example, all the functions are 1-1.

7.5 KLEENE ALGEBRA MODELS

7.5.1 FRAGMENT CONSISTENT KLEENE MODELS

Ordered computing structure have become a significant area for computing since (Scott, 1973). ADJ initial categorical computing and ordered algebraic definitions are based on categories, algebraic theories, and quotient structures. Functorial model computing as it has also appeared in the author's publications, applied generic models' diagrams. ADJ defines an ordered Σ-algebra and their homomorphisms with an ordering where the operations are monotonic and the homomorphism which are monotonic for the ordering defined. The ordering's significance is its being operation preserving. The author defined two decades ago on model-theoretic ordering for the initially ordered structures to reach for models for which operation preserving orderings are definable for a model theory on many-sorted categorical logic and its definability with finite similarity type. The ordering the author calls morphic might further be computationally appealing ever since computable functors were defined by us.

- **Definition 7.9:** A preorder << on a Σ-algebra A is said to be morphic iff for every σ ∈ Σs,s1.sn and ai,bi εAsi, and Bsi, respectively, if ai << bi for i ∈ [n] then, σA (a1.,an) << σB (b1.,bn). A Kleene algebra (Kozen, 1990) is an algebra A = (A,+, 0,;, 1, _) such that (A,+, 0) and (A,;, 1) are:

  monoids, with + commutative and idempotent, and satisfying (1) a(b + c) = ab + ac (4) 1 + aa* ≤ a* (2) a0 = 0 (5) 1 + a*a ≤ a*(3) (a + b)c = ac + bc (6) ab ≤ b ïZ a*b ≤ b

  0a = 0 (7) ba ≤ b ïZ ba* ≤ b. Denote by KA the class of models of these axioms, and write Horn(KA) and Eq(KA) for the Horn and equational theories of KA respectively.
- **Proposition 7.1:** Kleene structures can be granted with an initial model characterization with morphic Preorders.

We will apply fragment consistent model techniques to generate Kleene models. A tree game degree is the game state a tree is at concerning a model truth assignment, e.g., to the parameters on the Boolean functions on a game tree. Event algebras with monadic signature agents model consistent and complete computation logic.

7.5.2 ISL EVENT ALGEBRAS

A String ISL algebra (Nourani, 2005) is a Σ-algebra with an additional property that the signature Σ's has a subsignature Λ is only on 1-1 functions. We can define specific ISL event algebras based on specific signatures. For example, a Kleene ISL algebra is an algebra A (A,+,0…,1,*) such that (A,+,0) and (A:1) are monoids, with + commutative and idempotent, and satisfying:

(1) a(b + c) = ab + ac (4) 1 + aa* ≤ a*
(2) a0 = 0 (5) 1 + a*a ≤ a*
(3) (a + b)c = ac + bc (6) ab ≤ b ΐZ a*b ≤ b 0a = 0 (7) ba ≤ b ΐZ ba* ≤ b + and, assoicative respective, and a + 0 = 0+a = aa.1 = 1.a = a

- **Lemma 5.1:** String ISL algebra extending a Kleene algebra A (A,+,0.,1,*) such that (A,+,0) and (A,;,1) are monoids, with + commutative and idempotent, is Kleene.
- **Lemma 5.2:** String ISL algebra homomorphically extending an algebra A (A,+,0.,1,*) such that (A,+,0) and (A,;,1) are monoids, with + commutative and idempotent, is Kleene.
- **Theorem 5.1:** Let T be a ISL language theory. T is (a) a sound logical theory iff every axiom or proof rule in T preserves the tree game degree;(b) a complete logical theory if there is a function-set pair <F,S> defining a canonical structure M such that M has a generic diagram definable with the functions F.

7.6 EVENT PROCESS ALGEBRAS

7.6.1 COMPUTING MOTIVATION

A proof to Gödel's completeness theorem Henkin style proceeds by constructing a model directly from the syntax of the given theory. The structure is obtained by putting terms that are provably equal into equivalence classes, then defining a free structure on the equivalence classes. The computing and reasoning enterprise requires more general techniques of model construction and extension, since it has to accommodate dynamically changing world descriptions and theories. Our techniques for model building as applied to agent computing allows us to build and extend models with diagrams. The minimal set of function symbols are those with which a model can be built inductively. The models presented and applied are called intelligent. The models are Initial, i.e., unique up to isomorphism, and homomorphic to all models in the category of models definable with the specific generic diagrams. Specific agent term algebra models were presented and proved computable (Nourani, 1994)-Canonical Models from models to set theory had been stated for arbitrary structures as follows.

Generic diagrams allow us to define canonical models with specific functions. They are specific canonical models on agent term algebras presented at Nourani (1996a). In the sections above, we have shown how to define models with G-diagrams. Initial models are models definable by generic diagrams. A newer look at models and extensions since the author's two decades ago is to call a primitive set of operations of algebras of a class C is a set that implicitly defines the remaining operations. Pratt (1992) states given any class C of algebras of a given signature S, a subset T of S is called primitive for C when it determines the remaining operations of S, in the sense that any algebra with signature T has at most one expansion (same elements but additional operations) to an algebra in C. For example, either · or + is primitive for Boolean algebras because they each give away the underlying posset of the algebra, via a = a · b or a + b = b, which then determines all the Boolean operations. Authors two decades ago are on initial algebraic models that are obtained from a primitive set of operations, showing that the operations are definable with conservative extensions. The following 4 theorems from Pratt are interesting to observe towards primitives on what is on the following sections.

- **Theorem 6.1:** (Pratt, 1992)-the operations + and; form a primitive set for ACT.
- **Theorem 6.2:** ACT < KA.
- **Theorem 6.3:** Every finite Kleene algebra expands to an action algebra.

  From Pratt, let {L0,L1,L2.,Lω} be the set of languages of the form Li = {xj | j < i} for i = 0, 1, 2.,ω over an alphabet whose single symbol is x. This set is closed under the standard regular operations and has constants 0 and 1, namely L0 and L1, respectively, making it a subalgebra of the set of all languages on that alphabet and hence a model of REG. Now identify all its finite languages starting with L2 to form a single element F for finite. This equivalence can be verified to be a congruence, whence the 4-element set {L0, L1, F, Lω} is a quotient and hence also a model of REG. The above are example computing motivations to the following proposition. We can apply the above to obtain models as follows.

- **Proposition 7.2:** (Positive Process Event Fragments) Models for event expressions are created by defining a language category on the signature, where the preorder category has language fragment sets as objects and is preordered with the expression containments ordering.
- **Corollary 6.1:** Models for event expressions on Equational ACT are created by defining a language category on the signature, where the preorder category has language fragment sets as objects and is preordered with the pre-implication ordering.

The proof applies the consistency on fragment models, lemmas 6.4 and 6.5, on Kleene structures.

7.6.2 PRESERVATION THEOREMS ON CONCEPT DESCRIPTIONS

For transforming description logic into our categorical framework, we use notations from Nourani- Eklund (2016). Interpretations $I = (D^I, \cdot I)$, where I maps every concept description to a subset of DI, use D for that universe, which should not be confused with D as used for concept descriptions, e.g., in expressions like C D, where D is not to be understood as the "D in D^I."

With C as a "concept," we have $C^I \subseteq D^I \in P\, D^I$. This means that $P\, D^I$ is the actual 'algebra.' Roles R are semantically described as relations $RI \subseteq D^I \rightarrow D^I$, i.e., we can equivalently write it as a substitution R^I: $D^I \rightarrow D^I$.

The observation that relations $R \subseteq X \rightarrow X$ correspond precisely to functions (in the form of substitutions) R: $X \rightarrow PX$, where P is the powerset functor over the category of sets and functions, is the basis for viewing generalized relations as morphisms (substitutions) in the Kleisli category over-generalized powerset monads.

With C as a "concept," we have $C^I \subseteq D^I \rightarrow PD^I$. This means that PD^I is the actual 'algebra.'

- **Definition 7.10:** A Description algebra morphism h: $PD^{I} \rightarrow PD^{I'}$ where I and I' are alternate interpretation functions such that h preserves roles R on D.

  Following definitions on HA morphism and the state space agent model above, we have description algebras defined on an agent signature S. Considering a sequence description competitive model (Nourani-Schulte, 2014), a concept interpretation I correspond to a competitive model on an agent learning tree. Signatured agent trees satisfy goals to complete a model diagram realizing a role R. Concept descriptions are presented with an agent signature tree $T_{I\Sigma}$ with a role R defined on the signature agents.

- **Proposition 7.3:** A description by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma}$ algebra morphism on an agent signature algebra $T_{I\Sigma}$ by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma.}$

  Here we want theorems on Concept Descriptions corresponding to Theorems 5.1 and 5.2 in the ontology algebra paper published at Nourani (2014); IAT Warsaw (2014).

  Let us present the agent competitive instance for an algebraic description model platform.

- **Definition 7.11:** Let A and B be description algebras with intelligent signature IΣ containing agents. An IΣ-ontology description is an IΣ description algebra with a prescribed role R: $X \rightarrow \wp I\Sigma$ for the agents and functions on the IΣ signature.
- **Remark:** $X \subseteq I\Sigma$, so for a set monad, there is an assignment for all IΣ well-formed trees.
- **Theorem 6.4:** Let A and B be IΣ description algebras with the signature IΣ. Then the agent homomorphisms defined from A to B preserve IΣ-ontology iff defined by a description algebra homomorphisms by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma.}$
- **Proof:** Theorems 5.1, 5.2, and Proposition 7.3.
- **Theorem 6.5:** Let A and B be IΣ-description algebras with the signature IΣ containing KL agents. The AII with KL morphisms preserve IΣ-description ontology algebras iff defined by KL-Description ontology homomorphisms.
- **Proof:** Similar to 6.1. DKB mappings are specific ATL's where the ontology algebra operations are the same at source and target. We can prove based on the above that DKB mappings are DKB preservation consistent.

7.7 EVENT DESCRIPTION ONTOLOGY

7.7.1 LEARNING, CONCEPTS, AND ONTOLOGY PRESERVATION

Our transfer learning model applies the BID model to specify learning areas M1 and M2. Each area's BID is presented with intelligent signatures IΣ1 and IΣ2. Predictive model compatibility techniques are presented with agent signature game trees where the above formalism can is applied to realize competitive learning models. The following process is applied to transfer game tree and competitive model learning across domains since modeling and realizability are based on morphism preserved formulas.

The term ATL here refers to the process of abstract transfer learning from an abstract characterization of a world, or learning domain to a second arena or world. Thus ATL express the relationship between two forms of representations. The notion of abstract transfer learning are either algebraic or model-theoretic (algebraic logic) definitions. We refer to specifications of the form <O,A,R> as presentations that present an IM_BID system. We also expect a presentation of the form <I[O],I[A],I[R]> for the implementing abstract or concrete machine. The former could be the designer's conceptualization, and the latter the specification of the syntax and semantics of a programming language. Informally the A TL process is that of encoding the algebraic structure of the conceptualization of a problem onto the algebra that specified a learning machine, or a secondary BID specified world. The ATL process becomes that of defining specific agent and structural morphisms on the above BID algebras. Each of the functions defined by <O,A,R> are implemented by agents, that characterize the implementation function I:<O,A,R> → <I[O],I[A],I[R]> is to be defining a mapping I: <Alg[A],Alg[F]> → <Alg[I(A)],Alg[I(F)]>. We refer to Alg[A] and Alg [F] are what we call ontology algebras. The implementation mapping I defines wrappers to resources in a manner preserving the ontology algebra. Ontology algebras are multi-sorted algebras defining multiagent systems defined by formal agents, e.g., hysteretic or knowledge level agents and agent morphisms.

The ATL Ontology Preservation Principle, following is the first author's 1997 ontology preservation principles (Nourani, is: The ATL is a valid transfer only if it preserves the ontology algebras. Since the knowledge-base is essential to learning designs, let us carry on the ontology preservations to Widerhold's domain knowledge base algebra DKB consists of matching rules linking domain ontologies. There are three operations defined for DKB. The operations are intersection-creating subset ontology and keeping sharable entries. Union-creates a joint ontology merging entries. Difference-creates a distinct ontology and removing shared entries. Mapping functions must be shown to preserve ontologies. We can state-specific preservation principles as follows.

The DKB Preservation Principle-ATL must preserve ontologies under intersection, union, and difference operations.

Let us apply the definition for HA agents and HA morphisms to state a preservation theorem. Let A and B be IS-algebras with the signature IS containing HA agents. Let Alg[B] be an IS-algebra defined from B implementing (e.g., Nourani, 1993) a specified functionality defined by A. An ATL is an implementation for Alg[A] by Alg[B].

- **Definition 7.12:** A IS-homomorphism is an ISL Algebra morphism with signature IS. To define description morphisms we define ontology D-morphisms as follows.
- **Definition 7.13:** Let A and B be ISL S-algebras. An ISL-ontology D-morphism is an ISL S-algebra morphisms preserving the axioms for the ISL algebras.
- **Theorem 7.1:** Let A and B be IS-algebras with an ISL signature IS. The ontology algebra mapping morphisms defined from A to B preserve IS-ontology algebras iff defined by D-homomorphisms.
- **Proof:** Definition for the ontologies, D-morphism, definition, IS-algebras and IS-homomorphisms entail the IS-ontology axioms are preserved.

7.7.2 FORMAL CONCEPT DESCRIPTION ONTOLOGY ALGEBRA

FCA is abstracted on so-called "context," or "formal context," but is in the end just a relation on sets, $I \subseteq G \times M$, often written as and said to be a triple (G,M,I). G is called these to f "objects" and M these to f "attributes." However, neither objects nor attributes are given any specific syntactic structure. The call for intuitive meaning, but as such, there is no syntactic structure whatsoever based on which objects and attributes move beyond being just points in sets. This obviously makes real-world applications difficult to develop, and application content is all in that intuitive structure, and none of it is embraced by the syntactic notion itself.

Basically, in FCA, G, and M are indeed just plain sets, but in this starting point, they can be seen as objects in the category Set of sets and functions.

Further, even if in traditional FCA, the elements of those sets have no structure whatsoever, these sets can be provided with generalized structure (Eklund et al., 2014), which formalizes FCA categorically, thereby opening up possibilities to give "object" and "attribute" more precise meanings given their syntactic structure, also going beyond just using Set as the underlying category for FCA, and, adopting a much more generalized view on relations.

In traditional FCA, a so-called "formal concept," or just a "concept," is a pair (A, B), with $A \subseteq G$ and $B \subseteq M$, such that $A = \{g \in G \mid gIm \text{ for all } m \in B\}$ and $B = \{m \in M \mid gIm \text{ for all } g \in A\}$. A lattice, the so-called "formal concept lattice," is given for the set of all concepts by $(A1,B1) \leq (A2,B2)$ if and only if $A1 \subseteq A2$ (or, equivalently, $B1 \supseteq B2$).

Since there is no convention about how to use given names for objects and attributes in "informally constructed" names for formal concepts, combining names into names for concepts, or simply inventing the names otherwise, has become tradition within FCA. This, however, means that there is no terminological or ontology basis for FCA, but concepts themselves are seen as ontology objects. The ontology preservation areas will be further developed to present concept ontology mappings and preservations.

In the following subsection, we show how constructive and type-theoretic methodology can provide enriched structures for FCA. The constructive approach Paive (2002) adapts classical ALC to a constructive system using the two routes outlined above. The syntax of such a constructive system is the same in both cases. Concept descriptions in this constructive description logic CDL language obey the following syntax rule:

$$C, D \rightarrow A \mid T \mid \bot \mid C \sqcap D \mid C \sqcup D \mid C \rightarrow D \mid \forall R.C \mid \exists R.C$$

where; C, D range over concepts, A is an atomic concept and R ranges over names of roles, as before. As usual in constructive logics, since $\neg C$ is simply an abbreviation for $C \rightarrow \bot$ we do not need to consider it. In compensation we must add in the constructive implication of concepts, which in classical description logic is a derived concept. Also, it is just a convenience to have the true concept T, as it could be defined as $\neg\bot$. We are then within the realm of first-order logic IFOL. The type-theoretic approach shows how concepts as singleton concepts correspond to "individual concept," whereas syntactic powers of concepts correspond to "concept."

7.7.3 A CATEGORICAL CHARACTERIZATIONS

In this subsection, we point out that ∃ in ∃R.C as a modality is actually an informal symbol. Further, as typing comes into play, we show how C is syntactically ambiguous in this context as the underlying signature is not precisely described.

In the following, we use notations from Schmidt-SchaussSmolka (1991). Note that D for the universe should not be confused with D as used for concept descriptions, e.g., in expressions like C⊔D, D is not to be understood as D in D^I, where I is the interpretation. With C as a "concept," we have C^I as a subset of D^I, which in turn is an element PD^I, where P is the powerset functor.

The "existential quantifier" in ∃R.C is an "R-modality" applied to the power concept C.

The definition for the semantic expression $(\exists R.C)^I$ uses the existential quantifier that appears in the assumed underlying set theory. Concerning the underlying signature and related variables, in Schmidt-Schauss Smolka (1991), the situation is unclear, given the assumption about the existence of two further disjoint alphabets of symbols, which are called individual and concept variables.

Logically, variables are not part of any alphabet. Variables are terms, and as such, they are terms of a certain type. We should therefore speak of "individual concept" rather than "individual variable." Now typing of "concept" and "individual concept" comes into play, and we will need type constructors on level two of the so-called three-level arrangement of signatures (Eklund, 2016). As opposed to Schmidt-Schauss (1991), we say "concept" instead of "individual concept," and "power concept" instead of "concept."

The underlying signature must be formalized, where concept is a sort in the given underlying signature on level one. On level two, Pconcept becomes a constant operator, and a type constructor P is then used to produce a new type Pconcept, which in their 'algebra' will be understood, respectively, as D^I and PD^I.

Simply typed description logic can now be formally defined in lambda-calculus (Eklund, 2016). A concept on level one becomes a "singleton power concept" on level three, and the syntactic expression:

$$\exists R.C \mathrm{app}_{P(\mathrm{Pconcept}),\ \mathrm{Pconcept}}\ (m, \mathrm{app}_{\mathrm{Pconcept},\ P(\mathrm{Pconcept})}\ (R,C)).$$

where; m is the multiplication of the underlying monad, and app is the function type constructor.

7.7.4 PRESERVATION THEOREMS ON CONCEPT DESCRIPTIONS

For transforming description logic into our categorical framework, we use notations in. Interpretations $I = (D^I, \cdot I)$, where $\cdot I$ maps every concept description to a subset of DI, use D for that universe, which should not be confused with D as used for concept descriptions, e.g., in expressions like C D, where D is not to be understood as the "D in D^I."

With C as a "concept," we have $C^I \subseteq D^I \in P\,D^I$. This means that $P\,D^I$ is the actual 'algebra.' Roles R are semantically described as relations $RI \subseteq D^I \rightarrow D^I$, i.e., we can equivalently write it as a substitution R^I: $D^I \rightarrow D^I$.

The observation that relations $R \subseteq X \rightarrow X$ correspond precisely to functions (in the form of substitutions) R: $X \rightarrow PX$, where P is the powerset functor over the category of sets and functions, is the basis for viewing generalized relations as morphisms (substitutions) in the Kleisli category over-generalized powerset monads.

With C as a "concept," we have $C^I \subseteq D^I \rightarrow PD^I$. This means that PD^I is the actual 'algebra.'

- **Definition 7.14:** A Description algebra morphism h: $PD^I \rightarrow PD^{I'}$ where I and I' are alternate interpretation functions such that h preserves roles R on D.

  Following definitions on HA morphisms and the state space agent model above, we have description algebras defined on an agent signature S. Considering a sequence description competitive model (Nourani-Schulte, 2014) concept interpretation I correspond to a competitive model on an agent learning tree. Signatured agent trees satisfy goals to complete a model diagram realizing a role R. Concept descriptions are presented with an agent signature tree $T_{I\Sigma}$with a role R defined on the signature agents.
- **Proposition 7.4:** A description by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma}$ algebra morphism on an agent signature algebra $T_{I\Sigma}$ by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma.}$

  Here we want theorems on Concept Descriptions corresponding to the theorems in the ontology algebra paper published at Nourani (2014); IAT Warsaw (2014).

  Let us present the agent competitive instance for an algebraic description model platform.
- **Definition 7.15:** Let A and B be description algebras with an ISL signature IΣ. An IΣ-ontology description is an IΣ description algebra with a prescribed role R: $X \rightarrow \wp I\Sigma$ for on the IΣ signature.

- **Remark:** $X \subseteq I\Sigma$, so for a set monad, there is an assignment for all $I\Sigma$ well-formed trees.
- **Theorem 7.2:** Let A and B be $I\Sigma$ description algebras with the signature $I\Sigma$. Then the agent homomorphisms defined from A to B preserve $I\Sigma$-ontology iff defined by a D-algebra homomorphisms by algebraic extension on free signature tree $\wp T_{I\Sigma}$ such that roles are preserved on $T_{I\Sigma.}$
- **Proof:** Theorems above and Proposition 7.4.

Similarly, DKB mappings are specific ATL's where the ontology algebra operations are the same at source and target. We can prove based on the above that DKB mappings are DKB preservation consistent.

7.7.5 DATA FILTERING FOR KNOWLEDGE MANAGEMENT (KM)

Data filtering refers to strategies or techniques for refining data sets for what a user (or set of users) needs, without including other data that can be repetitive, irrelevant or even sensitive. Techniques to accomplish the above are naturally important with big data applications. Competitive model data filtering is the technique our research has developed over the past several years to apply nondeterministic model diagrams describing knowledge that specific user group can edge minimize with based on goal satisfiability (Nourani, 2018) IJCAI Stockholm. The value of big data is only multiplied by good data governance. Big data has big value, it also takes organizations big effort to manage well, and an effective governance discipline can fulfill its purpose. The techniques are in part augmented analogical learning.

Consumers have been pledging their love for data visualizations for a while now, and data mining with multimedia discovery is the area being explored.

Big data is a popular term used to describe the exponential growth and availability of data, both structured and unstructured. More accurate analyses may lead to more confident decision-making. And better decisions can mean greater operational efficiencies, cost reductions, and reduced risk. Our novel techniques apply nondeterministic data model diagram filters to sparse big data spaces: (Nourani, 2017), applied on Nourani-Fähndrich (2018). The health care application area was on our preliminary unpublished discussions (Nourani-Eklund, 2018), for example, on the following application areas.

For example, suppose several different Web sites contain medical information or provide medical e-commerce services. If these Web sites share and publish the same underlying ontology of the terms they all use, then computer agents can extract and aggregate information from these different sites. The agents can use this aggregated information to answer user queries or as input data to other applications.

The algebraic treatment for ontologies affords a precise mathematical basis for basic ontological modeling processes like class structuring, slots, and domain range on slot functions. For ontology modeling, one must define the facets of the slots. Slots can have different facets describing the value type, allowed values, the number of the values (cardinality), and other features of the values the slot can take. For example, the value of a name slot (as in "the name of a wine") is one string. That is, the name is a slot with a value type string. A slot produces (as in "a winery produces these wines") can have multiple values, and the values are instances of the class Wine. That is, produces is a slot with value type Instance with Wine as an allowed class. Wines produced by a particular winery fill in a multiple-cardinality slot produces for a Winery class. Signatured algebra models are basic techniques for characterizing slot fillers, types, and value maps on class hierarchies (Figure 7.3).

FIGURE 7.3 Example processes: Wayfinding model world knowledge.

7.8 CONCLUSIONS

Amongst important application areas for ontology model is robotics, ranging from basic tasking, agent computing, software agents, visual perceptions ontologies, biomedical or medicine, to RPA: robotics business processes. Blockchain financial transactions, economic exchanges are the newest areas. Modeling frameworks such as the REA (resource-event action) that are event process algebras accommodate ontology modeling. Our techniques allow modeling learning across class ontologies, and process models base on agent computing structural morphisms to model the ontology transfer processes. New application areas are in the predictive analytics economics areas (e.g., Nourani, 2018; Porello et al., 2020).

KEYWORDS

- **algebra models**
- **augmented analogical learning**
- **met-contextual**
- **ontology**
- **resource-event action**
- **robotics**

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