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# **Bounded Rationality in Agent Orientation - “Just-In-Time” Visual Pattern Recognition**

**PhD Thesis in Computer Science and Information Technology**

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Dedicated to the Ninetieth Anniversary of Lotfi A. Zadeh

**“Lucian Blaga” University of Sibiu,  
“Hermann Oberth” Faculty of Engineering  
Sibiu, 2011**

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Când munca s-a sfârșit și toate verigile au  
fost prinse în lanțul de neînfrânt, am văzut  
că eu eram cel prins în propriul meu lanț  
**RABINDRANATH TAGORE “Gitanjali”**

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# FIRST CHAPTER

## Introduction. (Bounded) Paradigmatic Shifts

*Every established religion was once a heresy*  
HENRY BUCKLE "Essays"

The paradigmatic shifts are far-reaching – albeit inexorably bounded, to pay respects to the main thesis concept – in the very *topic* (1.1), are mirrored in the *thesis* texture (1.2) and permeated (even) the *author* (1.3).

### 1.1. About the Topic

In the context of paradigmatic shifts “bounded” means “unfinished”. It entails a challenging *thematic context* (1.1.1) and a stimulating *historical context* (1.1.2).

#### 1.1.1 Thematic Context

Beyond the intrinsic hurdles involved by various paradigmatic shifts, there are deep divergences between computer scientists depending on their professional background – better said perspective – even when they agree as regards facts. A key instance relates to the very thesis kernel:

All stakeholders implicated agree that in a post-industrial (service-based society) most untrivial applications have to deal with decision making in dynamic situations and agree also that “dynamic” implies “uncertain”. Unfortunately, abridging an issue dealt with in 4.3.2, “uncertain” means practically (mainly, subconsciously) quite different things for:

- *Mathematicians*: uncertain = *unknowable*. If it can be obtained through computation and/or deduction it cannot be uncertain. Time does not matter – mathematics is atemporal.

- *Software developers* (mainly for automatic control): uncertain = *undependable* (either untrustworthy or variable or unknown).

- *End users* (real-world decision makers): uncertain = *undecidable* (first of all for future contingents). Decisions must be made “*Just-in-Time*” as defined by Toyota [158] for its inventory system, (According to the BBC, until the 2011 tsunami Toyota was never out of stock.) There simply *is no time* neither to wait for further information to appear nor to optimise using incomplete information.

Moreover, accepting the idea that decision making under time pressure is intrinsically nondeterministic is mentally uncomfortable. Its corollary regarding the non-algorithmic nature of decision support software is even more.

Though, no CSIT thesis in the domain of engineering sciences could avoid devising new software and illustrating it convincingly in an experimental model – no matter the label put on it. Asserting that *it must be non-algorithmic* is an unavoidable risk.

### 1.1.2. Historical Context

Within the EU2020 strategy *continuing education* is a key pillar for *sustainable development*. In this context the Sibiu University (LBUS) started a transdisciplinary research project aiming at continuing education in engineering affordable for a medium-sized East European university. The undertaking was launched focusing on a paradox: “Our present object of work (*teaching*) is neither present nor object, since it aims at a future, quite far away, process (*learning*). Why should the teacher focus on solving (*predictable*) problems, when the learner should focus on managing (*unpredictable*) situations?” [63]. Thus, the research is focused on:

- *heutagogy* (for *learning* as nondeterministic process);
- *educational chaoplexity* (for *teaching* as post-industrial service);
- *bounded rationality* (advanced from cognitive *limitation* to IT *mechanism*, to cardinal educational *guiding principle*).

The research was intended to be carried out through a PhD theses cluster including: a) this thesis; b) “Non-deterministic e-Teaching in Uncertain, Dynamic Environments. Experimental Model Based on Memetic Engineering” (scheduled for November 2012, [26]) and c) “Holistic Heutagogy for e-Maieutics-Based Lifelong Learning” (in a stage too unsatisfactory to be relevant and now practically abandoned). Since the four technical reports ceased to exist, being dissolved in the thesis, they will not be referred to explicitly. (However, to keep a trace of the chronological evolution, their presentation slides are still available [43], [44], [45], [42]. Likewise for [26], the only technical report so far for the second thesis mentioned.)

The last update of this thesis took place on October 26<sup>th</sup>, 2011.

## 1.2. About the Fabric

The thesis fabric refers to explaining *abbreviations* (1.2.1), setting up a fine-tuned *terminology* (1.2.2), and outlining the *contents organization* (1.2.3).

### 1.2.1. Abbreviations

Abbreviations are not always present (e.g., for the sake of expressiveness they are sacrificed in titles or in key sentences). The list below is an excerpt from [14].

AI:	Artificial Intelligence
AO:	Agent-Oriented
AOSE:	Agent-Oriented Software Engineering
API:	Application Programming Interface
BASYS:	Balanced Automation Systems
BR:	Bounded Rationality
CAS:	Computer-Aided Semiosis
COST:	European Cooperation in Science and Technology
CSIT:	Computer Science and Information Technologies

CSITAO:	CSIT focused on Agent-Oriented
CTED:	Continuing Education
CWA:	Closed World Assumption
CWW:	Computing With Words
DSS:	Decision Support System
EDCHY:	Educational Chaoplexity
GST:	General System Theory
GUI:	Graphical User Interface
ICT:	Information and Communication Technologies
IDE:	Integrated Development Environment
JIT:	“Just-in-Time”
LB:	Left Brain
LBUS:	“Lucian Blaga” University of Sibiu
MEng:	Memetic Engineering
ODUE:	Open Uncertain Dynamic Environments
OS:	Operating System
PrPidsDM:	Premises for Post-industrial Decision Making
RB:	Right Brain
SOSE:	SOSE1 + SOSE2 (“S” stands for both “Service” and “Semiotic”)
SOSE1:	Service-Oriented Software Engineering
SOSE2:	Semiotic-Oriented Software Engineering
UI:	User Interface

### 1.2.2. Terminology

For any exploratory research terminology is crucial. Above all, this first thesis within the EU2020 research cluster – and most likely the first authentically agent-oriented thesis in Romania – needed some major conceptual clearing up. Thus, to serve, clarify, simplify, coalesce, and explain all CSITAO research, a *Carnap-like glossary* [14] was initiated:

In line with Carnap’s approach in his seminal glossary in “Introduction to Semantics” [105] the definitions are contextual, (most of them) informal, with the undesired connotations explicitly mentioned. “In order to explain the approach, some key concepts need to be made clear up front for the following reasons (especially valid in sensitive matters [...]): a) Concepts are derived from a general perspective and often develop it further; b) Since perspectives are sometimes vague or subconscious, they are mostly *implicit* and they can remain hidden, whereas concepts have to be dealt with, hence they must be *explicit*; c) These implicit, sometimes fuzzy, connotations associated with (especially new) concepts often result in confusions that can be harmful; d) Using terms that are partially, and ambiguously, synonymous increases confusion and distorts any debate” [9].

For this thesis such an undertaking is *sine qua non* at various echelons as shown by the following examples (5.3.1, 5.4.4, 7.2.1):

- Fundamental concepts as “*algorithm*” or “*programming language*” must be redefined in line with post-industrial society requirements. First of all, in spite of being defined in a



FIPA standard [126] the very “*agent*” is deeply misunderstood even in PhD theses. For the EU2020 theses cluster both “*teaching*” and “*learning*” must be thoroughly revisited in the context of sustainable development.

- Divergent connotations of “*positive*” and “*negative*”: in real-world situations, negative feedback has huge positive effects, while positive feedback is extremely dangerous.

- New concepts are expressed even in English using debatable terms: “*chaoplex*” should suggest rather “*complex*” than “*chaotic*”; hence, the glossary proposes to accept only “*chaoplex*” in encyclopaedias and dictionaries and to eliminate “*chaoplexic*” since there is no “*complexic*” in English.

(For the time being, the EU2020 theses will host the glossary as appendix until it will become autonomous at European plane – hopefully renewing a proposal made by LBUS for the entire ICT domain and accepted in 2002 at EU level by COST 269 but abandoned in 2004.)

### **1.2.3. Contents Organization**

After this introductory chapter, the first attack on optimisation is launched (“Best Is Not Always Better”) in Chapter 2, including the problem definition and the approach. The State of the Art in Chapter 3 brings in also the main conceptual neighbourhood (e.g., Semiotics, Memetics). On this groundwork, the next two chapters present the thesis kernel, namely the main paradigmatic shifts defended: the new role of bounded rationality in the post-industrial era, focusing on the evolution “From Kelvin to Zadeh” (Chapter 4) and choosing GST as “Lingua Franca” for transdisciplinary communication, focusing on bounded rationality as twofold feedback (Chapter 5). The new paradigms are illustrated in Chapter 6 by two non-algorithmic mechanisms for word-based modelling: a multifunctional bar for decision input and a non-algorithmic service-oriented decision-making framework. Both mechanisms are integrated in experimental models: a conceptual model of post-modern educational chaoplexity (Chapter 7) and an implemented model for visual patterns (Chapter 8). The overall evaluation in Chapter 9 summarises the original contributions in four categories: conceptual pillars, apparatus, approaches and effects of serendipity; likewise, the problems emerged during the research – and still open – are grouped in line with the expected role the author can play in their future investigation. To keep relevance, enhance argument, and ease reading the comprehensive bibliography is split into two parts in line with the role played when referred to: recent (2007-2011) factual references (used mainly for the State of the Art) and all kind of other sources of ideas.

## 1.3. About the Author

To impair artificialness I will use here the first person, I try to explain the *motivation* (before starting the endeavour, 1.3.1), the *paradigmatic arguments* (during the research, 1.3.2) and to pay the sweet debt of *thankfulness* (1.3.3).

### 1.3.1. Motivation

Besides the usual incentives to start a PhD. in “Cybernetics and Economic Statistics”, after losing my doctoral adviser, the motivation to start PhD. in Engineering Science is obvious analysing the directions of my papers quoted in 2.3.

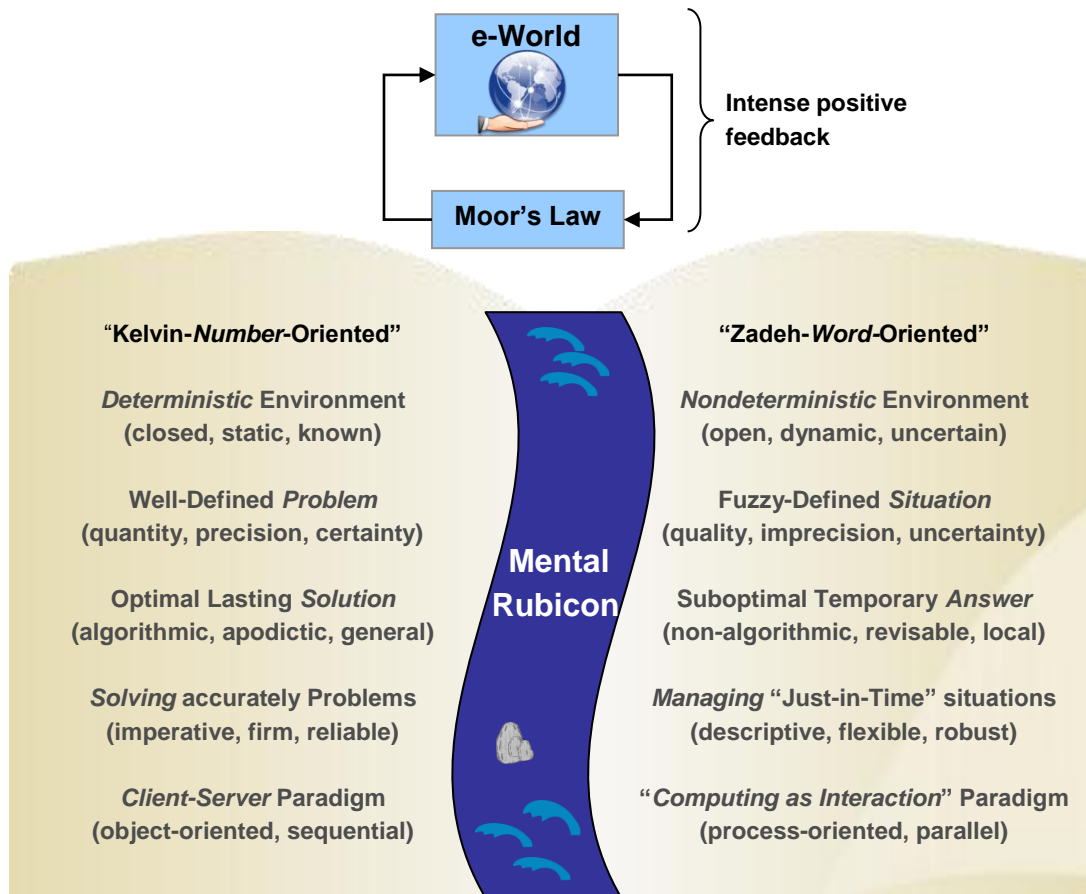
The first doubts about the universal effectiveness of conventional mathematics in IT applications were raised during my first doctoral studies (in 2002-2008) by two circumstances: a) the loose relationship between formal languages and real-world problems (e.g., the futility of compiler theory in modelling economic applications); b) the meagre practical results of applying traditional optimisation methods in any kind of modelling (e.g., the feebleness of popular algorithms in multicriterial optimisation). Thus, I was conceptually ready to accept the Simonian ideas about BR, first of all as regards the usefulness of approximation in anthropocentric interfaces (in agent-oriented context the problem was dealt with in [40]).

A key role played my evolving standpoint on cognitive science and its relationship to IT: as application developer trained in object-oriented programming I ignored it until my first research in artificial intelligence; then, being involved in agent-orientation I accepted cognitive science only as application field of CSIT – namely as modelling cognition based on sequential deterministic computation. Now, I accept the conceptual basis of Figure 1.1 but I still have (diminishing) doubts about the developing abilities of nondeterministic software for the time being.

On this groundwork my intentions are to keep walking on this way (first of all I intend to develop an Ada-like exception handler, 6.1.3), being engaged as much as possible in future work – above all as outlined in 9.3.1.

### 1.3.2. Paradigmatic Arguments

The thesis was more than a year under the stigma of delayed decision-making because of a (very late settled) paradigmatic disagreement between me and my doctoral advisor. In essence the divergence could be reduced hereto the well-known clash in AI – widespread nowadays in IT as a whole – between *objects* and *agents*, as explained in [35] and shown in Figure 1.1.



**Figure 1.1.** Crossing the Mental Rubicon (inspired from [35]).

Now the conceptual Rubicon is considerably narrowed in line with the diachronic perspective about *cognitive science* as detailed in 3.2.2.1. In short, the compromise defining the thematic context can be summed up as follows: the thesis is conceived as agent-oriented but the “service-providing software entity” reflected in the experimental model could be labelled as “agent” iff it is treated by the operating system as thread. Though, because of reasons given in 6.1.3, it was mandatory to accept the unpleasant implication that, in the absence of a genuine interface agent, the human service provider takes over a part of the tasks commonly carried out by interface agents.

### 1.3.3. Thanks

Looking back on all I have experienced throughout these years of my PhD study, I get deep feelings of gratefulness and surprise. There were certainly many people who shaped me as the person I am now, to whom I'd like to address my words of gratitude.

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for the incredible amount of energy he spent around the clock teaching me what research means – it did not matter how late at night or early in the morning it was.

My deep gratitude goes to the thesis evaluators; I thank Acad. Florin Gh. Filip for his thorough review and information regarding automatic systems, decision making and anthropocentrism; Dan Dumitrescu for his attention given to the results of the thesis guiding me on reformulating the original contributions, and Ioana Moisil for always providing a right way out of any complex situation.

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## SECOND CHAPTER

### Bounded Rationality Vs Chaoplexity: Best Is Not Always Better

*Man muss noch Chaos in sich haben um einen  
tanzenden Stern gebären zu können*  
NIETZSCHE "Also sprach Zarathustra"

Since there is no *tabula rasa* in PhD research, before defining itself as *problem* (objectives, starting point, road map, 2.2), the thesis presents its evolution as *topic* (2.1). Then, the key syntagms in the *title* are scrutinised (2.3) and the *approach* is outlined (2.4).

#### 2.1. EVOLUTION OF THE TOPIC AT LBUS

Work carried out before the PhD started is abridged as *prehistory* (2.1.1) and is followed by the two year *thesis period* (2.1.2). The *author's pre-thesis work* (2.1.3) ends the subchapter.

##### 2.1.1. Prehistory (2001-2009)

A compromise between the "no *tabula rasa*" principle (2.2.3) and the need to decree a point in time where prehistory begins is rather easy for exploratory research in CSITAO: at most a decennium. A "boundedly rational" deviation for this thesis is the century start year.

Research at the Faculty of Engineering (2001-2005) and at the Faculty of Sciences (2005-2009) represents the main strands (in parentheses are only the sources of main ideas quoted in this thesis):

- *Agent-Orientation*. As shown recently in [7], it "includes three distinct but interrelated fields: *interparadigmatic synergy* (mainly boosting temporal aspects in agents); *anthropocentric systems* (agent-oriented captology, multimodal analog human-agent interaction); *exception-based reactivity* (mainly pathematic agents designed as virtual therapists reacting to patient and environment stimuli). Approaches, results, and standpoint were presented in [93]".

Still related to agents but dealt with in more detail and playing the role of prolegomena for the paradigmatic shifts advanced by this thesis are:

- *Holism, Synergy, Complexity, Logic, Semiotics, Memetics, Psychology*. Agent-oriented anthropocentric systems are approached in [94], stigmergy-based synergy in [97], metaphors and memetics in [98] and [11], logics for agents (nonmonotonic reasoning, trivalent logics) in [100] and [17], semiotics (including languages, semantics, semiosis) in [95], [99], [15]. The reflection in non-algorithmic software is illustrated in [16], [6], [5].

- *e-Learning, Lifelong learning*. Since older work is strongly related to continuing education but less to bounded rationality, it is considered only in [26].

### 2.1.2. Historical Period (2009-2011)

The starting point of the EU2020 theses cluster is, “the broad outline of a strategy to journey "from Sibiu to Lisbon via Bologna", where a Rector joined the educated guess of a manager with the "educated vision" of a doctoral advisor: "education in the Knowledge Society would focus rather on *skills* than on *knowledge*"[65].” [63]

The problem of service-oriented approach to quality management was addressed very recently from a clear-cut engineering perspective as regards service architecture and from an agent-oriented stance as regards application structure in [68].

Transdisciplinary links in agent-orientation are dealt with in [67] where the impact of time-related concepts is underlined: a) designing *services* instead of *products*, involves *parallelism*, hence a powerful temporal dimension; b) to interact capably, client/learner and server/teacher must be somehow “contemporaneous” (this the huge challenge of continuing education). Later, BR was filtered in [40] “through the Sieve of the Lisbon Objectives”.

Recently, occasioned by two papers prepared for a Conference on Psychology, Counselling and Guidance [62], [61], the intrinsic thesis transdisciplinary vein become not just more manifest but influenced significantly the overall approach.

### 2.1.3. Author's Pre-Thesis Work

When I started my first PhD study (1.3.1) both the thesis topic and my conventional mathematical-IT background generated paper based on – or at least referring to – concepts difficult to defend as regards their applicative role in economics as: pattern matching and tree grammars [114], abstract state machines [116], algorithm for string replacement [113], fuzzy grammar, intermediate code [135], total fuzzy grammars [117], fuzzy extension on context-free grammars [39], syntactic pattern classification [37].

There were also some papers with valuable ideas for this thesis related to graphical user interfaces [115] and study program design [38]. The first paper directly related to the thesis objectives – representing also my first step toward a new paradigm – was [13] and one year later the second step with [54] and [73]. A less relevant step but in the right direction, namely transdisciplinary bridges, was [41].

## 2.2. DEFINING THE PROBLEM

Any important journey is predefined by its *objectives* (2.2.1), *starting point* (2.1.2), and *road map* (2.1.3).

### 2.2.1. Objectives

After each objective is a short comment, mainly a mini-rationale for its current formulation:

**1. *Revisiting thoroughly the concept of bounded rationality, in view of its roles in a post-industrial (service-based) society.***

Since the major new role of BR as “educational mechanism” is hard to confine in the classical conceptual framework, two expansions are necessary: a) *Choosing a Lingua*

*Franca for holistic approaches able to promote transdisciplinarity (above all as regards psychologists). b) Expressing bounded rationality in terms of General System Theory.*

**2. On this groundwork, substantiating the ambivalence of bounded rationality (cognitive limitation and IT guiding principle) within the agent-orientation paradigm, in applications destined to perform in dynamic and uncertain environment).**

Since no cooperation with psychologists could be started, three expansions were necessary to achieve the objective: a) *Investigating preterminologic BR (mainly the anthropogenetic divergence between optimization and simplicity).* b) *Exploring the role of BR as “psychological stabiliser” (through negative feedback).* c) *Extending the analyse to (largely preterminologic) synergy as (boundedly rational) resource amplifier.*

**3. Instantiating this approach for continuing education, via a framework able to manage educational chaoplexity based on bounded rationality as common denominator of, mechanism for, and connection between the two facets of continuing education: e-teaching and e-learning.**

Because the educational instance (within the EU2020 theses cluster) had to be advanced due to the much stronger link to cognitive psychology (involved by the expansions of the first two objectives), the initial framework was detailed with three subobjectives closer to the related thesis [26] than to this one but included (temporarily) here for the sake of consistency: a) *Investigating post-modern “educational chaoplexity”.* b) *Exploring e-teaching as boundedly rational system.* c) *Boosting e-teaching via extrapolating lasting topics and behaviours.*

**4. Validating the approach by carrying out an experimental model of a nontrivial service to be provided (from a holistic perspective, within a user-centred application) by an agent-oriented interface in uncertain and changing environments. To ensure the qualitative validation soundness, the application field chosen is “Visual pattern recognition”.**

Besides the prudence entailed by the lack of confidence in the easy accessible APIs [146] (commented upon in 1.3.2) the main selection criteria were: a) any service quality assessment in continuing education is still rather moot; b) there are several widespread benchmark programs for convincing comparisons; c) both holistic approach and “Just-in-Time” response are quintessential; d) it opens a valuable gateway towards validating the fifth objective too.

**5. Exploring the paradigmatic shift towards building Computer Science rather on semiotics than on mathematics.**

The first results achieved in approaching BR transdisciplinary, allow trying to recycle – at least partially – the unfinished research in Computer-Aided Semiosis as well as the various attempts to devise facets of bodiless agents. However, the high engineering research risk involved, confines the enquiry to the aspects able to be reflected in the experimental model.

### 2.2.2. Start Vector. (Premises and Working Assumptions)

Neither premises nor working assumptions are negotiable (details in 2.4.1). This thesis is based on six premises (*Pr*) and six (ad hoc) working<sup>1</sup> assumptions (*Wa*):

*Pr1*: In post-industrial (service-oriented) engineering failure is ruled out for vital services (because some of them are “vital” in the very sense of the word) [65].

*Pr2*: Post-industrial (service-oriented) nontrivial applications are intended for intense interaction in open, heterogeneous, dynamic and uncertain environments (OHDUE).

*Pr3*: All established results of GST and its related sciences (mainly cybernetics and synergetics), as mentioned in Chapter 5, are accepted as premise.

*Pr4*: Both *decision making* and *learning* are cognition-based, nondeterministic, processes that operate in dynamic and uncertain environments; hence, they cannot be modelled *deterministically* and cannot be described adequately by *algorithms*.

*Pr5*: Agents are *processes* devised as *interactants* not *objects* devised as tools [59], [35].

*Pr6*: Precision is costly [87].

*Wa1*: The very concept of bounded rationality involves suboptimality in nontrivial applications [13].

*Wa2*: In line with *Pr1*, decision-making support applications based on conventional algorithmic software are either *unaffordable* (with scarce resources) or *ineffective* (as regards end-user expectations) [64].

*Wa3*: Analog input is *natural* (the human mind is visually oriented), *general* (for any usual linguistic variable), *effective* (fast, robust, ergonomic) and very *easy to implement* [16].

*Wa4*: Cognition is (regarded as) holistic and boundedly rational. (The parenthesis is necessary because an apodictic assertion about the very nature of human cognition is outside the competence of computer scientists and hence unacceptable in a CSITAO thesis). As a result, here only the relationship between cognition and decisional or educational systems seen as *cybernetic* and *intentional* is dealt with.

*Wa5*: Precision is useless [35], [64]. To pay tribute to Zadeh’s work [64] this assumption is called “*Rationale 3*”.

*Wa6*: Precision could be harmful when decision is urgent (“Just-in-Time” decision making) [35], [64]. For the same reason, this assumption is called “*Rationale 4*”.

### 2.2.3. Road Map Based on Idoneity. (Criteria)

After clarifying the inflexible points of *finish* (2.2.1) and *start* (2.2.2), choosing the *road* reinstates the *flexibility* – cardinal for any research and *sine qua non* for PhD research in Engineering Sciences. It depends on the criteria. In principle, they are also rigid *per se* but their blend is negotiable: they can be chosen based on idoneity. Thus, the major paradoxes – sometimes even antagonic requirements – can be lessened. Therefore, in exploratory research – above all in CSITAO – listing a set of clear-cut criteria is neither necessary, nor

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<sup>11</sup> Here, “working” has the same pragmatic connotation as in the syntagm “working definition” [8].



sufficient. However, it is mandatory to set up also a second road map: a “Plan B”, based on agent-oriented software engineering (AOSE) tenets. Indeed, since CSIT remains a branch of engineering and since exploratory research in AO is more risky than in other areas, every CSITAO PhD work should have a standby solution (see also *Pr1*). Some examples for this thesis:

- *No Tabula Rasa*. Beginning from scratch is avoided by reshaping previous work (favoured by the free choice of thesis topics).

- It seems rather obvious that – without daring to assert “the end of reductionism” – cognition can be studied only macroscopically, i.e., holistic, within cybernetic intentional systems (5.2). Though, since it is not CSITAO this claim stems from<sup>2</sup>, it cannot be regarded here just as working *hypothesis*, not as *assumption*.) Anyhow, on this groundwork it can be argued that: a) a service must be evaluated *in corpore*, by the end user in a subjective manner and against some tacit – even changing – expectations. That implies at least two key approach features: *successive prototyping* and *qualitative validation* (see 2.4).

- Of course, *static* knowledge should be replaced by *dynamic* knowledge. However, how can *tacit* knowledge be *voiced* in (temporally distant) e-teaching?

- What means “unaffordable (with scarce resources)”? A less fuzzy formulation than that in *Wa2* could be: “affordable for a medium-sized East European university in difficult times” or “in the near future”.

In short, flexibility means withdrawing in idoneic manner from the first to the second road map. This thesis was forced to do it in the experimental model: the mechanisms (6.2, 6.3) were *conceived* for “Plan A” (continuing education) but *developed* for “Plan B” (visual pattern recognition, 8.1.1-8.1.3).

## 2.3. EXPLAINING THE TITLE

On the groundwork of the apodictic 2.1 and the revisable 2.2, the four syntagms in the title can be explained - and their subliminal messages suggested.

### 2.3.1. Bounded Rationality

The term “*Bounded Rationality*” is used as defined, explained and endorsed in [155], [156], [157], [153], [128], [129], [127]). The connotations involved by this thesis, given in [13], entail that “almost any undertaking to be effective, must resort to the *force of imperfection*. Indeed, in AI context, *perfection* suggests the dream [...] to achieve algorithm-based optimisation not taking into account the computing time involved. [...] Here [...] time is gained giving up the “force of perfection”. That means to acknowledge that in real-world applications, it is illusory to hope for well-defined (if possible, monocriterial) problems, complete information, accurate data, acceptable time restrictions, low risk, conventional business, etc. and for being able to give optimal solutions through scores of

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<sup>2</sup> Even its origins are debatable: cognitive science, cognitive psychology, GST, Eastern tradition, philosophy?

<sup>3</sup> To avoid fruitless philosophic arguments, the term is used as shorthand for the generally acceptable syntagm: “macroscopically perceptible”.

<sup>4</sup> My italics.

<sup>5</sup> “*return-type*” is meant to emphasise that the analyse is language independent. However, it is presupposed that the OS

exact data (if possible, output offline and sequentially). On the contrary, most problems are multicriterial, online, and distributed, supplied with incomplete, fuzzy, and/or uncertain information – arriving in parallel, in huge amounts and in unpredictable moments –, in the context of critical response time, high risk, virtual enterprises, etc. Thus, the challenge is to *manage situations*, since there is no time to *solve (accurately) problems*. The solution must arrive "Just-in-Time" and be acceptable suboptimal" [13].

### 2.3.2. Agent Orientation

The term "*Agent-Orientation*" is used as defined and explained in detail in [93] and endorsed by the definition of "agent" in a FIPA standard [126]. In the context of BR, anthropocentric systems, *Pr5* and *Wa4*, much more relevant than individual (weak or strong) agent features are: a) the agent metaphor (making decision in behalf of humans, agents are non-deterministic *par excellence*); b) affordability implies bodiless interface agents for any kind of services as well as toy problems; c) despite its relative simplicity, an interface agents must be modelled as *process* and implemented as *thread* (i.e., as atomic, sequential, asynchronous, and dynamic entity); d) for this thesis the interface agents for the experimental model could not be reliable if programmed neither in mark-up languages, nor with existing APIs. Thus, "the unpleasant implication" (1.3.2) of acting somehow as its own interface agent will be the less bad solution for this thesis. That is the minor significance of "agent-orientation". Though, the major meaning in the title is: in the effort to assimilate a paradigmatic shift it is often necessary to dare to assert– not only in a PhD thesis – that *architecture* always prevails over *structure*. Thus, since the thesis architectonic is clearly agent-oriented, albeit no piece of code is labelled as agent, the syntagm should be in the title.

### 2.3.3. "Just-In-Time"

From the two-echelon perspective of the thesis its role in the title is: a) for this thesis it is agent-oriented mechanism (3.4.2); b) for the thesis as keystone of the EU2020 research cluster, it is paramount because, as response time (3.4.1), it states the feature of non-deterministic dialog, basic for the shift from *product* to *service*. For this very shift, from a slightly different perspective, "Just-In-Time" has also a new third role: c) it is regarded as main current connotation of "real time" (3.4.3). The new role is crucial for the thesis setting due to three reasons regarding learning based on bounded rationality because:

- it is inherently associated with the role as response time, vital in any teacher-learner interaction (not only in "socratic duologue", 7.1.3);

- it is illustrated in the implementation of the two non-algorithmic mechanisms (6.2, 6.3) as well as in their integration into the experimental model (8.4.1, 8.4.2).

- it concerns not just this thesis but the whole research cluster related to EU2020 where it achieves another vital – albeit paradoxical – connotation: continuing education involves a "JIT synchronization" between e-teacher and e-learner [26].

### 2.3.4. Visual Pattern Recognition

It was always in the title but changed its *raison d'être* each year. Abridging its history is telling for illustrating that: a) despite being *terra incognita* exploratory research needs very flexible intellectual road maps; b) paradigm changes are sometimes mentally painful:

- 2009. It appeared as a compromise between the fear of lacking a credible experimental model for daring new ideas (author's stance) and the chance to prove holistic cognition avoiding the programming difficulties involved by the temporal dimension of interface agents for service-oriented applications (advisor's stance).

- 2010. The EU2020 theses cluster offered the challenging test-bench domain of continuing education but no chance whatsoever to prove the engineering soundness of an experimental model. Taking advantage of previous LBUS incremental research in this area [143] it seemed worth to pay the price of lessening the link between the target application domain and a recently investigated domain full of verified algorithmic benchmarks.

- 2011. The successful – and as unexpected as serendipity entails – development of two mechanisms, proved to be easy to implement after having the courage (or very odd idea?) to simulate the nondeterministic behaviour of a complex interface agent by the decisional (macroscopic<sup>3</sup>) free will of its owner (6.1, 8.2, 8.3). Thus, the toy problem domain was not necessary anymore but is still useful for its engineering relevance. Moreover, improving image transmission becomes obsolete (8.4.1); hence, related benchmarks too.

## 2.4. APPROACH

After setting up the approach framework (2.4.1), the three fundamental approach dimensions are scrutinised: *anthropocentrism* (2.4.2) is required by any service-oriented project, *transdisciplinarity* (2.4.3) is required by any (meta)model of continuing education while *microcontinuity* (2.4.4) is *sine qua non* for any experimental model. Most quotations and ideas stem from a paper about engineering education [65] and one about transcultural communication aiming at convincing psychologists to move on from “inter-” to “trans-” disciplinary approaches to permanent education [7].

### 2.4.1. Applying the Start Vector. Adapting the Criteria

The approach is based on the nonnegotiable *start vector* (2.2.2) and on the adaptable *criteria* (2.2.3). All fight conformity, i.e., express intellectual adherence to the service-society paradigms but the criteria admit implicitly that a variable time is needed to assimilate them in behaviour. Thus, the adapted approach criteria are the following:

- *Bounded rationality versus “Just-in-Time”*. In the approach are taken into account only method-related paradigms. These two, albeit content-related, are here being essential for post-industrial engineering altogether and being paramount for exploratory research: “*Just-in-Time*” is required to respect reasonable time limits while *bounded rationality* is the

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<sup>3</sup> To avoid fruitless philosophic arguments, the term is used as shorthand for the generally acceptable syntagm: “macroscopically perceptible”.

most affordable means to meet the theses deadlines within rational limits of accepted risks. (In fact, they are both “fortunate limitations” and so interlinked in human reasoning that they could be stated vice versa too: “Just in rationality” and “Bounded time”.

- *No object-orientation*. Any approach to develop “object-oriented agents” including related languages, platforms or mechanisms – e.g., AUML, JADE, mutex – is not just irrelevant but confusing and counterproductive.

- *What Dennett stances are suitable* [93], [96] (details in 4.2)? A *mechanistic* stance is inappropriate because rising software complexity (e.g., in concurrent engineering, or when managing a virtual enterprise) entails a similar user stance: the application is viewed as a *machine*. “Since the user grasps complexity only through the interface, any such system boundary – labelled or not as “interface agent” – should fight both kinds of complexity involved: *structural* (to increase system effectiveness it must be hidden) and *cognitive* (to increase user acceptance it must be reduced). Therefore, a black-box approach is required by the emphasis on *ergonomics*, emblematic for any engineering endeavour (“easy to understand, easy to use”). On the other hand, a key feature of engineering is its *process* nature (that holds from management to development, to the very object of work). Thus, agents are more suitable, being the only software type explicitly conceived as *processes* (though, they are not mandatory)” [65]. Of course, when agents are complex (2.4.2), the intentional stance is most appropriate (when the environment is chaoplex, such a stance is mandatory *because* of BR!).

- *Simulating the e-maieut*. The target of [5] was “to introduce the concept of *eMaieutics* [...] and to illustrate it in experimental models, where *maieutics* is action-oriented (i.e., promoting rather dynamic than static knowledge) and highly personalised, while “e-” is carried out through virtual entities interacting with the learner as interface agents” [5]. “According to this definition, *maieutics* is not affected by replacing the virtual entity by a living one. (On the contrary, in theory, a “carbon-based” teacher is a much better interface agent than a “silicon-based” one – in any case at the present level of the two species.) Even as regards “e-”, simulation is legitimate because [...] all facilities offered by conventional e-learning, from search engines to “learning objects repositories” rest available [65].

### 2.4.2. Anthropocentrism

As a constant concern of CSITAO research it was promoted by LBUS as key word of EU scientific cooperation in 2005. Its significance was recently emphasised again in [7]:

“An important step towards emphasizing the necessary user primacy [...] was the explicit reference in the COST 298 Memorandum of Understanding: “The third area involves the development and promotion of an anthropocentric perspective in developing broadband ICTs (i.e. how such ICTs should be user-pulled rather than technology-pushed)”. However, here “*anthropocentric*” has two [...] connotations: for the wide-ranging target it means a *stance* (without a human-centred perspective transdisciplinarity is vain – in all meanings of the word) while for the current objectives it embodies the very *approach*. [T]he anthropocentric approach mirrors itself in both application *architecture* [...] and *message conveyed*” [7].

For the EU2020 cluster anthropocentric approach is the backbone of any credible application. If teaching is not a human-centred service, what is it all about? (Indeed, narrow-minded expressions intended for robots like “machine-learning” or “learning algorithms” sound unacceptably outworn in continuing education. More details in [26].)

There are three facets of anthropocentrism that revolutionise IT application development. Each of them could be sufficient as *raison d'être* for this thesis:

- *Holistic approach*. This aspect is most important since, if some undemanding and very predictable services could be canned – and handed over to machines or primitive robots – no service whatsoever could be assessed (or not even adequately provided) if conceived as decomposable, i.e., reduced artificially to “components”. Hence, programs that can be – and usually are – separated into basic ingredients as algorithms, objects, DLLs, and so on must be treated cautiously or avoided altogether. On the contrary, approaches based on right-brain style are welcomed to supplement the limited left-brain algorithmic approaches. Moreover, for this thesis, only merging synergistically such approaches (e.g., in non-textual pseudocode for agent-oriented interaction, 8.3.1, 8.3.4) could be restored the “holos” of the human brain, where BR comes from.

- *Architecture vs. Structure*. Almost as corollary of the above, architectonic aspects are far more pertinent than structural details. Answering to “*What* new features are provided?” is crucial for the experimental model, whereas answering to “*How* are such features implemented?” is cared for only when solving minor programming tasks.

Some principles of “anthropocentric design”: “a) Of course, the job has to be easy for the human, not for the machine, i.e., the interface complexity should be the burden of the system, not of the user. b) The evolution from interacting with an *instrument* towards interacting with an *assistant* has to be recognized and promoted. c) Anything visible to the user regarding the system behaviour or structure, excepting the interface, is useless and might become harmful” [96]. For the end user there is no application, there are only features accessible through an interface [125], [121], [120], [104].

- *Agent-orientation*. Corollary of anthropocentric development: “unable to manage the system complexity involved by current IT applications, humans must transfer most of this complexity to the system” [10] (elaborated upon in 5.2.2, 6.1.2).

In short, CSIT becomes CSITAO to signal the need to regain in the *post-industrial* era the *control over technology* (almost) *lost by humans* in the *industrial* era.

### 2.4.3. Transdisciplinarity

“Prigogine’s idea that the most interesting scientific activities seem to occur at domain interfaces is a confirmed [...] path for applied research [...]. Academic research is confined to find “Prigogine niches”; they can be found mainly through innovative, emerging technologies [...]. That means *transdisciplinary* niches. Besides being *promising* and *affordable*, the third reason for “Prigogine niches” is the *synergy* reachable through transdisciplinarity. Indeed, whereas for any researcher a *violon d’Ingres* acts as an intellectual amplifier, for a research team it tends to become an intrinsic ingredient of the scholarly structure [...]. Any transdisciplinary approach to a “Prigogine niche” is yoked to a double vicious circle: to a-

void failure, both choosing the *problem* and proposing its *solution* require transdisciplinarity. It is more dangerous than a common "begging the question" since it affects not just reasoning but deed too. The picture looks even worse when modern IT is involved because of: the amazing speed of innovation [...]; the increasing end-users dissatisfaction [...]; the inertia of critical Zeitgeist-constituents" [7] (and work cited there).

Although being found frequently in exploratory research, a transdisciplinary perspective is not mandatory as such. The need for transdisciplinarity was increased – at least in the case of this kind of research – through the inability of IT people (CSITAO researchers included) to convince social scientists that they need each other. Indeed, the failures were caused mainly by the inexorable dilettantism entailed by monodisciplinary (IT) approaches to real-world problems.

Hence, for a CSITAO PhD research *anthropocentrism* (here seen more than just an *approach*, namely seen as *target*) and *transdisciplinarity* (as *means* to achieve it) are *sine qua non* requirements entailed by the very nature of services. The prefix "trans" insinuates – if not an opposition to "cross", "multi" etc. – that modern complex service providers have to cooperate seamlessly. (That holds even more for agent developers. Hence, both the transdisciplinary orientation of the third chapter and the fifth chapter as major extension of the thesis scope were necessary.)

#### **2.4.4. Microcontinuity. Successive Prototyping**

"An obvious corollary of anthropocentrism (as both stance and approach): the interface must be designed involving the users from the very beginning. For both theoretical and practical reasons "micro-continuity" is mandatory: a stepwise proceeding is safer, cheaper, and workable within the narrow scope of a PhD. Another central feature is "modularity", entailed here also by research reasons: micro-continuity implies incrementally extendable functionality of the interfaces. Thus, both transdisciplinarity and affordability are boosted. More common approach facets (e.g., rapid and/or successive prototyping, generic architecture) have been described in [5], [99]" [7].

Moreover, a CSITAO application should be "designed iterating a design-implementation-evaluation cycle, saving re-implementation time since the first design is based on empirical knowledge of user behaviour. Anyhow, the design of truly anthropocentric systems has to be carried out by interdisciplinary teams" [96]. For instance to communicate successfully "agents should manifest stepwise human-like behaviour. Here micro-continuity can help since not the *anthropomorphic feature* itself has to be replicated, but its *appearance*" [10]. If a complex agent-based interface is not fitting, at least multimodal communication should be provided.

To conclude, there are two hallmarks of the approach shift: a) intense focus on transdisciplinarity; b) more daring communication modalities in the experimental model:

a) The attempt to use the *General System Theory* (GST) as *Lingua Franca* for psychologically-oriented transdisciplinary addressees was much more than a linguistic bridge. Indeed, it proved to generate a powerful *positive feedback* – in all meanings of the syntagm

– yielding the third Chapter (2.2 much more consistent than expected, the rest merely through serendipity).

b) The (new) challenges in the model concern *nontextual* – maybe even *nonverbal* – communication in the dialog between the service provider and the end user. In the case of this thesis it regards both mechanisms (6.2, 6.3) and their integration into the experimental model (8.1).

## THIRD CHAPTER

### Bounded Rationality in Humans and Agents. State of the Art

*If you cannot get answers keep putting questions*

After adapting the “*State of the Art*” guidelines [14] to this thesis (3.1) and enhancing the investigation about *transdisciplinary bridges* (3.2) the scrutiny is focused on the *basic concept* (3.3) and on the *basic paradigm* (3.4) respectively.

#### 3.1. ADAPTING THE “STATE OF THE ART”

“*Adapting*” has here two meanings: a) the *synchronic* connotation refers to *fine-tuning the guidelines* in line with the thesis targets (3.1.1); b) the *diachronic* connotation refers to updating the first technical report (first version: November 2010) and integrating it seamlessly into the thesis. That means refreshing both *sieve* (3.1.2) and *magnifier* (3.1.3). All the quotations are from [14]. (In parentheses are the immediate consequences upon this thesis.)

##### 3.1.1. Fine-Tuning the Guidelines

Beside the three familiar roles – found in almost all theses – the “State of the Art” report has here two new roles: the fourth is related to the latest condition of Computer Science whereas the fifth is a kind of self-experiment motivated by the research objectives of this thesis as well as by the need to be integrated in the EU2020 research cluster.

-*Filter for (exploratory) research.* Tributary to our own biologic and cognitive bounded rationality (BR), to be able to finish a PhD research report “Just-In-Time” (JIT), it is wise to bear in mind the first IT sub-domain aimed at fighting the mixed blessing of BR, namely Data Mining. To put to good use the mining metaphor, when trying to present the “State of the Art” of an artificial intelligence (AI) sub-domain – above all when new paradigms are concerned as involved by this thesis – it is needful to have both a very reliable *sieve* and a customary *magnifying glass*. Otherwise, it is nearly impossible to separate the information nugget from the huge data ores pushed in front of the researcher by just a few Google searches. (Indeed, in exploratory research the main risk in retrieving relevant information is not to fail to notice – almost inexistent – novelty, but to be drowned in spam.)

- *Start vector for developing the thesis ideas* (2.2.2, 2.2.3). Besides being an origin for estimating research value added, for exploratory research it must be also a roadmap outline, i.e., an educated guess about the most promising research directions in order to keep the delicate balance between adventuring into the unknown (the “*hic sunt leones*” inherent to any exploratory endeavour) and achieving an unmistakable end-user value. For short: it is a first risk-management indicator.

-*Stem cell for the third chapter.* To avoid the frequent trap of perfectionism – particularly risky for the fifth role – the emphasis should be on the sieve rather than on the magnifi-



er. Hence, before its final version as Chapter Three, this report was updated in March, July, and in early September 2011.

- *First infrastructure for the experimental model.* Given that the PhD degree is in “Computer Science and information Technology” (CSIT) as branch of Engineering Sciences, it inherited from Engineering the constraint to substantiate (at least) the main thesis objectives through an experimental model that embodies the main research results. Thus, the report had to gather the necessary information to build a functional model, namely an embryo able to become later an application.

- *Exercise in heutagogic metalearning through self-recursion.* Since a closely linked thesis had to deal with heutagogic (meta)learning, the idea is to apply recursively BR to itself, i.e., to employ it in investigating its very role in agent-orientation (AO). In short: testing self-recursion as metalearning tool to be applied in continuing education. (The experiment was rather unsuccessful for most CSITAO theses; moreover, the EU2020 thesis involved was abandoned.)

### 3.1.2. The Sieve. Thesis Non-Objectives

“To separate the wheat from the chaff, it is vital to assert what the thesis is not about” [14].

- *Incremental research.* That is the paramount restraint since the fourth objective “may lure to exaggerated circumspection in approaching” the targets. (Here the novelty of the thesis objectives makes this risk negligible.)

- *Industrial society.* “Nothing should refer to a product-based society or to whatever of its Zeitgeist components. The research is rooted in and dedicated to the post-industrial (service-based) society. (Any reference to conceive of agents as something else than service-providers is avoided as going against the trends in CSIT.)” [14] (It results unmistakable from the objectives.)

- *Conventional CSIT paradigms.* “It is a cardinal restraint since in Europe – and in Romania even more – the agent is still considered to be rather a program than a process”. [14]. (Idem. Moreover, it is a leitmotif of the thesis architectonic.)

- *Pattern recognition.* As explained in detail in 2.3.4 this most natural field where BR reveals itself, was chosen as test field because there are several widespread benchmark programs enabling indisputable validation of the research results. Thus, this subfield is regarded to be outside the thesis scope. Only some prevailing algorithms and their corresponding benchmarks are referred to.

- *Computer vision.* From the thesis perspective it is considered just a popular means to attain artificial pattern recognition. (Idem. Even more.)

- *Principles of subfields the thesis is strongly related to.* Despite its osmotic interference with other fields (e.g., cognitive science, psychology, biology, epistemology, logic, GST) the thesis is *trans* – not *multi*-disciplinary. Elements of other disciplines are not purposely looked for since CSIT is just a means to illustrate them. However, being unable to start a genuine cooperation with social scientists [62], [61], this restraint was not obeyed to the fullest extent, entailing the major risk of dilettantism.

### 3.1.3. The Magnifier. Keeping Roots in the Real-World

For CSITAO the magnifier is essential for keeping roots in real-world situations and should be employed – this time successively – for fine-tuning the research from the perspective of the following key elements (the order is relevant but not mandatory):

- *Locality in time (Moore's Law)*. To show that its effects are not limited to IT but tend to become a Zeitgeist component, just one example: Virilio's "logic of speed" [7]. (Here, to follow JIT the trends in CSITAO, the references are split into two lists: the first is meant primarily to defend the experimental model and contains mainly very recent papers – those published before 2007 will be rather "mature" in 2012 – while the second unfolds the idea sources and, thus, contains mainly books and seminal papers.)

- *Locality in space (ODUE)*. Equally important, since it delineates the validation setting for the research results. (Since services usually cannot be canned in a closed, thermodynamically governed environment, for CSITAO are thinkable only applications dedicated to perform in Open, Dynamic, and Uncertain Environments (ODUE).

## 3.2. TRANSDISCIPLINARY BRIDGES

Applying self-recursion to a kind of higher-order metaphor it could be speculated that such bridges are meant to simulate the accessibility relations between two possible Kripke worlds: "Despite the fact that the e-World is already "real" and the real world becomes increasingly "electronic", the conceptual gap between them is yet vast. To shrink it, we need trans-disciplinary approaches, able to integrate biased perspectives. The starting point is an analysis of the basic concepts (including main myths and metaphors)" [98]. Today they are seen as *memes* (3.2.1). Of course, the chapter core is 3.2.2, linking *cognition mechanisms* to BR. On this groundwork, two essential facets of "BR in action" can be investigated: *Semiotics* in 3.2.3 and *Memetics* in 3.2.4 as distinct bridges, namely from primarily architectural perspectives. (Finally, the bridges will be united in 5.4 to boost *transdisciplinary synergy*.)

### 3.2.1. From Myths, Through Metaphors to Memes

"Obviously, the major scolio in our time as a replicating entity metaphor is the nature of the thing that the time-element (as an object) actually is in the objective world. [...]. Indeed, [...] it is possible to imagine time as consisting of elementary "chronons", comprising ancestors and successors, and that each element-successor is able to eliminate its corresponding element-ancestor. This notion is reminiscent of Greek myths, in which intrinsic forces mediate the flow of time. [...] Classic myths about time, in which Uranus, Chronos [...], and Zeus, are the major characters, have in common an internal father-son or son-father obsessive annihilation. [...] In neoplatonic philosophy, and particularly among the orphic fragments, an obscure time-god entity (Chronos) is primarily responsible for the unfolding of the universe (the Hegelian *Entwicklung*) [...]; that is, time as a primary engine" [91].

This (too long) quotation shows that: a) *metaphors* stem from myths even for very complex problems; b) archetypal *myths* generate sophisticated scientific *hypotheses*; c) when *myths* spawn long living *metaphors* they tend to become *memes* (details in 3.2.4).

For instance, two “myths are hindrances not only for a beneficial cooperation between real and e-world, but even for the mere acceptance of the second one [...] a) modern IT and first of all e-world are a big threat to humanist values; b) AI is worse: “Frankenstein redivivus” threatens humankind itself. [...] Indeed, as any “Zeitgeist”-component, those myths engender a treacherous corollary: widening the gap between humanists and technologists, they impair transdisciplinarity” [98].

*Metaphors* are semantic transferences between two domains ([137] quoted in [93]) and thus “are a promising path to shrink, or at least elucidate, the gap between the diverging perspectives and to prepare us for overstepping the mental Rubicon separating humanists from technologists. To be effective for the group aimed at, a metaphor supposes a “common” language as source (e.g., plain English: laptop, window, icon) and an “uncommon” one as target (here, several IT jargons). Nevertheless, three hurdles still exist: a) often, the source language is not “extremely common” (e.g., portal, virus, cloning); b) sometimes it is worse: pre-existent, not every day, metaphors are used to create new ones (e.g., avatar, cyberspace, Trojan horse); c) when the metaphor has the stronger features of an analogy it is looked at as model, before it actually becomes or is overestimated (e.g., recycle bin, information kiosk, robot); d) if the metaphor is indeed the foundation of productive models, it is predisposed to be taken as dogma (e.g., genetic algorithm, artificial intelligence, virtual therapist). Thus, to keep the endeavor manageable and the approach effective, in the proposed framework, the real world is used just as “metaphor engine” while metaphors are used (firstly) just as catalysts for brainstorming” [98].

In short [8], metaphors are deeply rooted in myths (psychologists are aware about the mytho-magical thought tendency in the right brain hemisphere); mainly in IT, myths are valuable sources of metaphors (for instance, “avatar” could be considered an effective catachrestic metaphor). “Caveat: when myths become prejudices they impair paradigm shifts (e.g., Mayan Calendar: end of time at December 21, 2012 = end of world)” [8]. Worse, they could be quite dangerous when they act as *toxic memes* (examples in 3.2.4). Moreover, for agent-oriented software, metaphors play “[e]ssential role in all development stages (when elusive concepts – as self, time – are involved): conceptualising (creative in brainstorming); modelling (without a biological model at hand); selecting reasoning strategies (inferences by induction, instinctive analogies); implementation (extrapolating examples, selecting toy problems, validating in ovo)” [8].

### 3.2.2. Cognitive Psychology, the Protecting Pillar

To catch the trend, the nuanced evolution of Thagard's perspective (from 2005 to 2010) – having the weight of a *Stanford Encyclopedia of Philosophy* – is highlighted below.

#### 3.2.2.1. Cognition. Where Does It Stem From?

“Cognitive science approaches the study of mind and intelligence from an interdisciplinary perspective, working at the intersection of philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology” [159].

After five years, the stance is slightly different (my italics, RDF): “Cognitive science *is* the interdisciplinary study of mind and intelligence, *embracing* philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology” [83].

Cognitive science started “in the mid-1950s when researchers in several fields began to develop *theories of mind based on complex representations* and computational procedures. [...], Thagard's systematic descriptions and evaluations of the main theories of mental representation advanced by cognitive scientists allow students to see that there are many complementary approaches to the investigation of mind. The fundamental theoretical perspectives he describes include logic, rules, concepts, analogies, images, and connections (artificial neural networks). The discussion of these theories provides an integrated view of the different achievements of the various fields of cognitive science” [83].

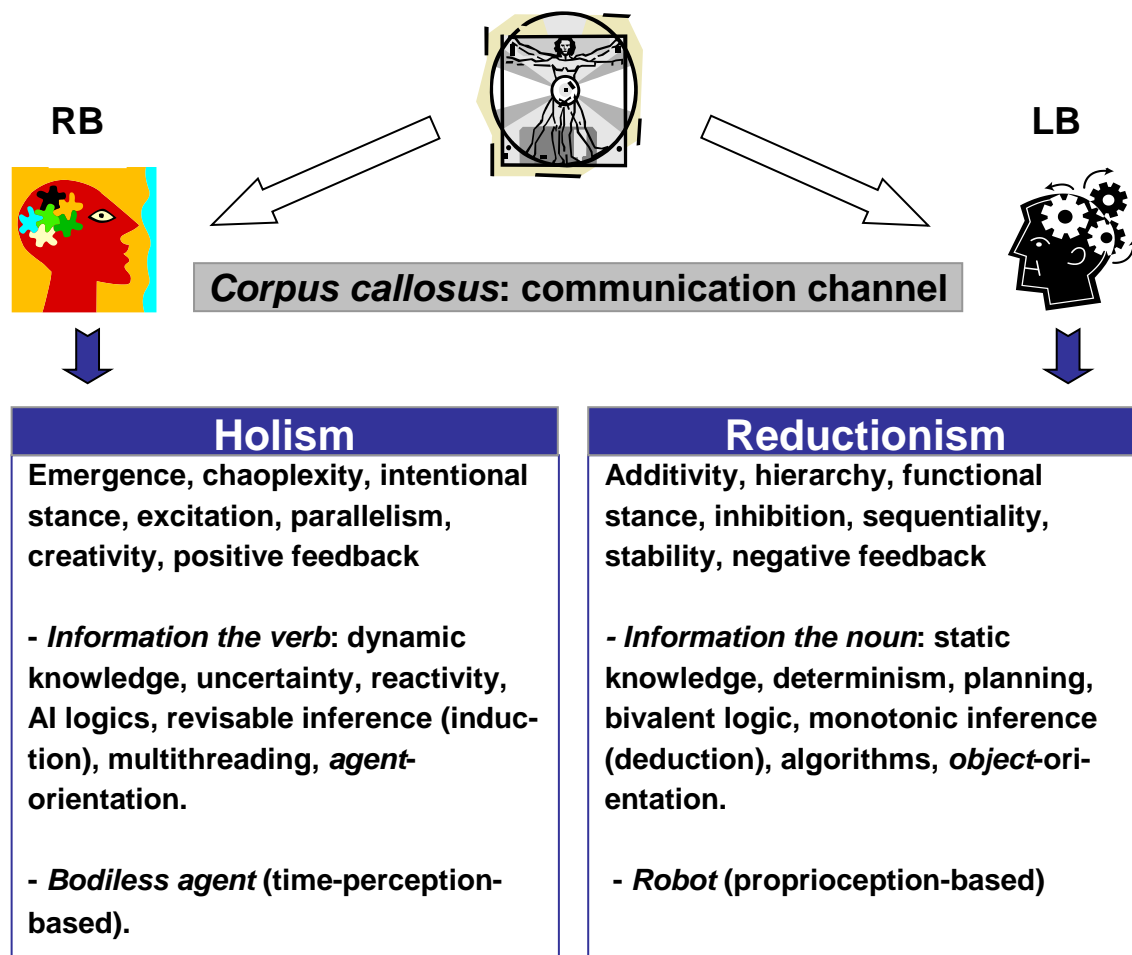
*In nuce*, if the “intentio lectoris” construal of Thagard's position is correct, it could be inferred also from the titles of his determining works on this topic, beginning with “*Mind: Introduction to Cognitive Science*” (this was the main source of both information about and critique of cognitive science that governed the research perspective in the prehistory of CSITAO, since its publishing in 2005, through its reflection in *The Stanford Encyclopedia of Philosophy*); “*Philosophy of Psychology and Cognitive Science*” (2007), “*Why cognitive science needs philosophy and vice versa*” (2009); “*The Brain and the Meaning of Life*” (2010) [83] (this has for the EU2020 cluster the role played in the past by the 2005 work).

#### 3.2.2.2. Holism vs. Reductionism in CSIT

The ironical caption of Figure 3.1 shows that the holistic approach was yet hardly able to go beyond a half of a brain. Definitely, it is not enough! The oversimplification is – at least partially – caused by the reductionist approach still prevalent in cognitive science: cognition can be modelled only computationally and computational approach is confined to the left-brain (LB). What about the right-brain (RB)? Indeed, its role cannot be uncared for anymore, neither tabooing it (Cartesian gap between “*res cogitans*” and “*res extensa*”) nor ignoring its very existence (La Mettrie's “*L'homme machine*”).

Figure 3.1 is inspired from earlier CSITAO research (mainly [35], [12], [8]), represents now the stance of thesis EU2020 research – and implicitly the approach framework for this thesis. Thus, many concepts it refers to will be elaborated upon in the next chapters.

On the other hand, “LB-oriented” research is very consistently illustrated in [36].



**Figure 3.1.** Boundedly rational and reductionist image about holism.

Here self-recursion has to take over, requiring that the “very human research BR” should guide investigation, (re)turning to an inherently anthropocentric approach. i.e., to an – at least preliminary – “organoleptic” line of attack. Thus, we feel that we are not computers, our rationality is bounded, our decision making is hard to explain, and so on. For this thesis feeling-based beliefs are paramount: *heredity*, *tradition*, and *environment* count, no matter of genetics or of enculturation.

Somehow as corollary, we feel that our way of thinking – no matter of cognitive psychology – is a stable pillar and protects us against the terrifying speed of environment changes – first of all those made by humans. Now it is possible to express a transdisciplinary research proposing BR as “cognitive engine”, using scientific terminology (Chapter 5).

### 3.2.3. Semiotics, From UNES to Emoticons in Communication

Semiotics entered CSITAO research through several ways because a service-based society requires at the same time, parallelism, temporal dimension and intense communication between service provider and user. Previous work is abridged in 3.2.3.1 and a constant concern of CSITAO – outside the strict scope of this thesis – in 3.2.3.2.

### 3.2.3.1. *Computing with Words, Sounds, or Gestures*

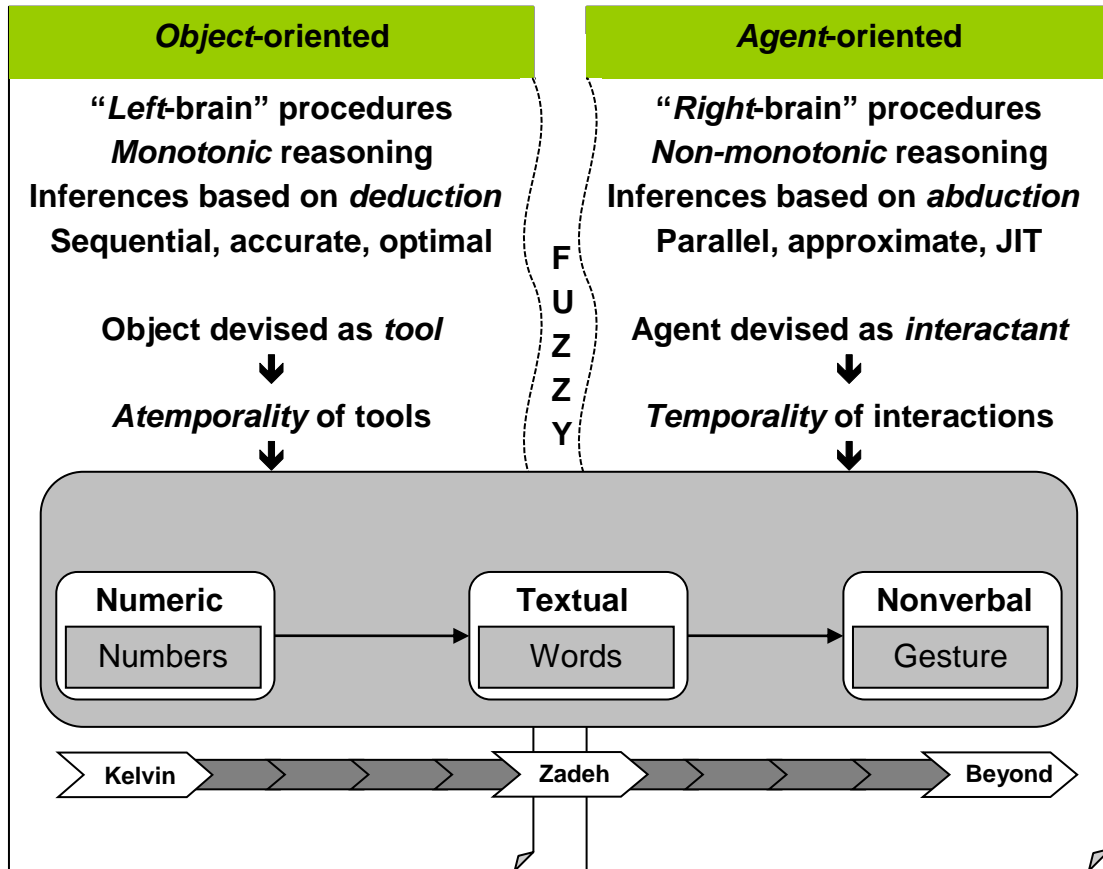
“Most mathematicians – and some computer scientists too – overlook the major paradigm shift in IT: from "client-server" to "computing as interaction" in open, dynamic, and uncertain environments. This shift is due mainly to Moore’s law and to its consequences: Internet, broadband technology, agent technology, Google, and so on [35] [...]. As a result: a) cardinal concepts (approximation, uncertainty, granularity, etc.) are either ignored or misunderstood; b) the requirement that IT solutions must come "Just-in-Time" (JIT), implying bounded rationality (BR) as fact of life is disregarded. Regrettably, the “Weltanschauung”-gap is widening both horizontally ("humanists" and "technologists" become less transdisciplinary) and vertically (“Kelvin-number-oriented” and “Zadeh-word-oriented” computer scientists are pushing artificial intelligence in opposite courses of action)” [8]. In the prehistory of this thesis, some reusable results were achieved in the following agent-oriented domains (unfortunately, the related PhD theses were abandoned):

- *Computer-Aided Semiosis (CAS)*. In [15] “an affordable manner to "invent new Computer-Aided x" application domains is proposed. To substantiate the approach, the domain must be immediately useful, challenging, easy to implement and "as humanist as possible": Computer-Aided Semiosis. [...T]he message receiver understands the meaning of the message through the process of semiosis, i.e., thus the receiver "fills the message with significance" [112]; hence it is vital for any communication and is strongly dependent on the cultures involved" [111]. Likewise, “the new kind of "less data-oriented computing" (Zadeh’s “computing with words”) can be extrapolated to “computing with gestures" [15].

- *Protensional Agents*. “Early research in Computer-Aided Semiosis [...] required two basic steps ahead: to consider also sounds and to deal with music. Thus, to use the expressions in Chandler [...], both graphocentrism and logocentrism could be avoided. [74]. Besides the liaison to the wide-ranging research path of emulating Husserlian time, investigating protensity has strong motivation “If computers have to deal with meanings, they should be first able to assist end-users in a basic process that was until now an exclusive human attribute: semiosis. [...] If atemporal text or images can be accepted as messages [...], why temporal sound-based messages could not be treated likewise? [...] Because of the unidirectionality of time, uncertainty is much more important in time than it is in space” [74]. This agent was followed by an also unfinished “model of an agent able to interpret protensity-based messages, designed to act as e-maieut (now, as virtual guitar teacher). The approach is based on theories of internal representations of external objects (because protensity-based messages are treated as such objects). The focus is on mechanism effectiveness: the agent treats limited aspects of sounds involved in playing guitar (correctness of the scales played by the learner, freely or in the context of various chord progressions)” [47]. In short, it was an attempt to employ semiotics to prove Hermann Hesse right: “Music is aesthetically perceptible time - present time. And this reminds us of the identity of moment and eternity” [www.autumn-eu.de/music.html].

### 3.2.3.2. Nonverbal communication

The research legacy of primeval nontextual communication abridged above is put into effect in the thesis and reflected in the experimental model based on the guidelines shown in Figure 3.2 (inspired from [8] where semiotics was for the first time referred to as foundation for devising bodiless agents with Husserlian time).



**Figure 3.2.** Multiple paradigmatic shift in the theoretical foundation of semiotic-based bodiless agents.

As regards the strange title of 3.2.3, it hides some subliminal messages:

- Semiotics has a tremendous preterminologic history (when hardcopies were yet carved in stones).
- Semiotics has also a tremendous comeback (when hardcopies tend to become useless).
- The portmanteau word “emoticon” is telling: the very blend shows that conventional text was unable to convey anthropocentric messages (icons are much simpler and stronger even for primeval emotions).
- The runes were chosen as starting point for the semiotic journey – albeit their “second century newness” in comparison to much older writings – because they were (and to some extent still are) much more than letters or even instances of skaldic poetry: runes were transcribed metaphorically as “kenningar” [102] (a very rich concept, from the Old Norse verb *kenna* “know, recognise; perceive, feel; show; teach; etc.”

[.wikipedia.org/wiki/Kenning#Etymology], creating an educational riddle – perhaps one of the first European applications of BR in continuing education. Thus, the rune ᚱ (“Reid”, “ride”) was the answer of a riddle contrasting the rider’s luck to the horse’s effort. Moreover, some runes got memetic character – unfortunately the rune “Sol” written twice conveyed a very toxic memplex.

### **3.2.4. Memetics. An Engineering Perspective**

Including memetics here among transdisciplinary targets is arguable because: a) it is yet in a syncretic stage; b) memetic engineering – its technological arm – all the more; c) neither BR nor “Just-in-Time” need to go further than metaphors; d) perhaps not even reorienting CSIT towards semiotics should need it. Nevertheless, there are at least three reasons – corresponding to three levels – to consider it in this thesis (the intermediate “EU2020 level” is dealt with in [26]):

#### **3.2.4.1. Scientific Status (CSITAO Level)**

Why “Another new “.... tics”?” [8]. The same paper gives also some answers giving the examples of the well-known “Self” memetic complex [11] and of Husserlian time:

- Memetics is a key Zeitgeist-component and is transdisciplinary par excellence.
- Most paradigms in modern AI have an obvious memetic character.
- The “Self” memotype shows a cognitive complexity similar to the structural one of the genotype.
- The “Self-\*” memplex invaded modern IT (“star” = awareness) [...]
- The thick-time meme is vigorous and old (preceded AI itself) [8].

Even if the scientific status is yet syncretic, memetics – mainly as unnamed phenomenon in an increasing chaoplex world – has already an undeniable (albeit sometimes subliminal) ideologic role: “Cognitive: ideas perceived as cogent by most in the population who encounter them. Cognitively transmitted memes depend heavily on a cluster of other ideas and cognitive traits already widely held in the population, and thus usually spread more passively than other forms of meme transmission. Memes spread in cognitive transmission do not count as self-replicating”. [<http://encyclopedia.thefreedictionary.com/Meme>].

#### **3.2.4.2. Memetic Engineering as Antidote to Vicious Memes (Thesis Level)**

As shown by the examples given in 3.2.1, for this thesis – and for CSITAO as a whole – some urban folklore can be harmful when myths are not dismantled before being disseminated as memes. The need to counteract them is obvious and memetic engineering is just the newest arm in the well assorted panoply of persuasive means, from ancient rhetoric to modern aggressive advertising (details in 5.3.1). The long quote from [164] relates to an archetypal case and conveys abridged what this neophyte is all about: “It is well-recognized that public opposition to nuclear power is largely based upon an irrational response to real or imagined risks. Efforts to alleviate this through education and communication have met with some success, but inevitably encounter a barrier that some have called the “Dread Syndrome”: a deep and almost visceral fear initiating an immediate negative response, independent of external stimuli. The response is subconscious, and



therefore unlike public concern for many other technologies. [...] Nuclear power's perception displays classic memetic traits in that it is contagious, replicating, mutable, and has significantly affected sociocultural evolution since its first "infection" of the collective [...] consciousness. That it is a particularly strong and resilient meme, and therefore one that experiences increasing rates of growth, is self-evident. [...] A meme programs its own transmission through its host. Memes propagate through communication – in books, movies, television shows, media reports, songs, paintings, and in simple conversation. As with genes, a meme need not be necessarily "good" to survive; it is sufficient that it be strong and replicate quickly. A meme that satisfies this requirement will tend to appeal to the senses, or reinforce a fundamental desire, instinct, or bias. It will self-generate and spread exponentially, once introduced into a fertile medium. Memetic replication is infinitely more rapid, of course, than its genetic analog, since the generation time is that of a single thought. This has two implications, both sobering: (1) a single individual can have a profound and rapid effect upon sociocultural evolution in his/her lifetime; and (2) the evolutionary pressure from competing memes is immediate and constant" [164].

On the other hand, "memetic engineering perspective helps risky research to get academic acceptance" [8]. This holds not only for EU2020 theses but for CSITAO as a whole.

In short, after exploiting Dawkins' parallel to genetics, since "Darwin (natural selection) is too lengthy, let us try Lamarck" [8] as a kind of "software epigenetics".

### **3.3. BASIC CONCEPT: BOUNDED RATIONALITY IN SERVICE-ORIENTED SYSTEMS**

Starting from the (implicit) keywords the first search expression was "Bounded Rationality" + Agents + Complexity + Optimization". However, because relevance depends not just on quantity but on diversity too, the restriction was relaxed to "Bounded Rationality" + Agents + Optimization", giving over 86,000 results – any scope extension being irrelevant. Passing from the sieve to the magnifier, the focus was on authors of seminal papers (beside Simon, for instance Gigerenzer, Selten, Sugimori), newness (except sources of ideas, from 2007) and impact (e.g., more than hundred citations). As a result, *bounded rationality instead of optimization* (3.3.1) deals with the concepts themselves. Only optimization is ignored because of "Instead"; its connotations are the ordinary ones as set up by its very etymology, definitions (in mathematics or operational research) and its use (first of all in IT). Then, *bounded rationality* is explored as *necessary condition* (3.3.2), i.e., as confining anthropocentric research effectiveness to acceptable *cognitive complexity* (vital for continuing education strategies involved in the EU2020 program). At the end *bounded rationality* is explored as *sufficient condition* (3.3.3), i.e., as efficient mechanism to reduce *structural complexity* in the experimental model.

### 3.3.1. Bounded Rationality Instead of Optimization

To avoid misinterpretations, this “State of the Art” *does not* aim at:

- Defending the very principle of bounded rationality (a half-century of scientifically uncontested history after being developed by the Chicago School and endorsed brilliantly by Simon [155], [156], [157] makes it futile).

- Describing “models in which procedural aspects of decision making are explicitly included” (it was convincingly done by Rubinstein in [153]).

- Advising bounded rationality as a means to improve economic modelling – the reason Kahneman received a Nobel Prize (it suffices to read his lecture when receiving the Prize [141]).

- Linking it to psychological (or psychosomatic?) processes or to communication faults that could explain (or not) ill-applied statistical thinking in decision-making, because Gigerenzer proposed already alternatives for decision-making, based on simple heuristics that “lead to better decisions than the theoretically optimal procedure” (en.wikipedia.org/wiki/Bounded\_rationality); for instance, *priority heuristics* [128], [129], [127]).

The problem is that none of the aspects mentioned above as “non-targets” are taken into account sufficiently (at least, here and now), neither in *modelling*, nor in *decision-making* whatsoever. Thus – almost as corollary entailed by the very research – this severe sieve required an equally scrupulous magnifier. The results are spread all over this thesis, beginning with 4.2 where the impact of BR is thoroughly reinterpreted.

*Mutatis mutandis*, the same applies to BR as weapon to fight complexity, both cognitive (3.3.2) and structural (3.3.3).

### 3.3.2. Necessary Condition (to Fight Cognitive Complexity in Architecture)

“How can anyone be rational in a world where knowledge is limited, time is pressing, and deep thought is often an unattainable luxury? Traditional models of unbounded rationality and optimization in cognitive science, economics, and animal behavior have tended to view decision-makers as possessing supernatural powers of reason, limitless knowledge, and endless time. But understanding decisions in the real world requires a more psychologically plausible notion of bounded rationality” [128] quoted in [29].

For agent-based domain problems [75] is conclusive “First, we empirically demonstrate that people, or even the agents they write [...], are poor optimizers. Even when we explicitly asked two different groups of over 70 people to write agents to optimally solve a problem, and an optimal solution existed, they instead chose to use approaches that fell well short of optimal behavior. Thus, [...] encapsulating human behavior based on optimal strategies is not effective for certain domains. Second, we find that key elements of Aspiration Adaptation Theory (AAT) do effectively encapsulate many people’s search strategies above other bounded rationality theories [...]. Thus, the result in this paper is particularly important, and indicates the importance and greater generality of AAT, even in problems where optimal solutions exist. [...] following conclusions about how to write agents that better interact with people or simulate human performance. First, optimal methods should not

be used as they do not realistically encapsulate most human's behavior. Instead, bounded methods should be created such as those based on AAT. [...] For future work, several directions are possible. First, while we found that people's strategies fell short of optimal behavior in both optimization problems we studied, we assume that people will write rational and optimal agents in simpler problems. [...] Second, we hope to study how effective the above general conclusions are in simulating human behavior in these and other domains. Finally, we also hope to study how people interact with agents based on AAT [...]. Specifically, we hope to study agent-human interactions in an emergency response domain". [...] In both economics and computer science the perspectives of unbounded rationality based on notions such as expected utility, game theory, Bayesian models, or Markov Decision Processes [...], have traditionally been the foundation for modeling agent's behavior. While many important insights have been gained by these perspectives, it does not necessarily provide a descriptively correct model of human decision-making. Indeed, previous research in experimental economics and cognitive psychology has shown that human decision makers often do not adhere to fully rational behavior. [...] even in the best of circumstances, modeling behavior based on full rationality may be impractical. [...] Recent evidence from experimental economics provides support that people apply boundedly rational procedures [...], in real-world domains" [75].

[110] introduces a new behavioral platform for decision-making: "H. A. Simon coined the term "bounded rationality" using the metaphor of a pair of scissors to describe how humans' "cognitive limitations" interact with the "structure of the environment" in a way that restricts decision-making to a search process guided by "aspiration levels" for a goal variable that must be reached or surpassed by a satisfactory alternative".

[30] "provides three fundamental and generic approaches (logical, probabilistic, and modal) to representing and reasoning with agent epistemic states, specifically in the context of decision making. In addition, the book introduces a formal integration of these three approaches into a single unified approach [...] P3 (Propositional, Probabilistic, and Possible World) [...].The classical logic and probability theory thrust of our approach naturally excludes from our consideration other potential symbolic approaches to decision-making such as fuzzy logics".

A rare case when undecidability is discussed outside mathematics is in a sociological context where the authors "suggest that as well as being able to consider organizational decision-making as an instance of (albeit bounded) rationality or calculability, it can also be regarded as a process of choice amongst heterogeneous possibilities" [28].

[53] "offers a reconstruction of Herbert Simon's decision theory from the conventionalist point of view. It is argued that Simon defined two types of conventions in organizational settings: the first one was specified as a set of customary rules in the workplace, the second one as a shared cognitive model of reality. This paper emphasizes the importance of that approach for economic psychology and its connections with T. Schelling's project of the reorientation of the game theory. The implication of revisiting Simon from the conventionalist viewpoint is that not only may such an approach provide a solution to coordination problems, which is psychologically reliable, but it also leads to a decision

paradigm, according to which understanding problems of coordination is impossible without taking into consideration individual cognitive limits and social representations of reality". [155] cited in [53]: "If (. . .) we accept the proposition that both the knowledge and the computational power of the decision maker are severely limited, then we must distinguish between the real world and the actor's perception of it and reasoning about it".

In [16], starting from the premise that the "very concept of bounded rationality involves suboptimality in most nontrivial applications" stigmergy-based emergence was used to fight cognitive complexity.

Bounded rationality was investigated "through the sieve of the Lisbon objectives" in [40] and implicitly applied in transdisciplinary niches (via "interface agents for transcultural communication" in [7]).

An essential – and very good conceived book – covering the theoretical (logical vs. biological) foundations of bounded rationality in the context of "human reasoning and cognitive science" is [81]. Unfortunately, even important and very recent books [72] still regard bounded rationality rather as computational limit for agents than as biological limit for humans (that could and should be exploited in artificial but anthropocentric agents too).

### **3.3.3. Sufficient Condition (to Fight Structural Complexity in Implementation)**

[144] "examines the use of evolutionary programming in agent-based modelling to implement the theory of bounded rationality". "Human transformation of the Earth's land surface has environmental and socioeconomic impacts that extend from specific locales to the entire globe. We know surprisingly little about this land change".

[79] applies bounded rationality to boost the synergistic effect of computer science and game theory.

[78] "describes a simulation approach for modelling decision making processes under incomplete and imperfect information in Agent-based Computational Economics [...] The method translates some basic sociopsychological concepts from the bounded rationality and learning literature into an executable algorithm [...] applied in the domain of behavioural game theory, illustrating how the algorithm can be used to reproduce observed patterns of human behaviour".

[88] "presents the Adversarial Activity model, a formal Beliefs-Desires-Intentions (BDI) based model for bounded rational agents operating in a zero-sum environment".

[52] deals with supplier integration: "current rigid supply chains seem to struggle with the dynamic of the environment. Frequent changes of customer preferences and demand as well as dynamic political and economical conditions do pressurize companies to continuous adjustments. If a company is embedded into integrated supply relationships the impact of the adjustments at other supply partners have to be taken into account as well. Thus, more time is needed due to an extended decision-making process, which in turn reduces a companies' flexibility and may decrease its competitive capabilities. This trade-off between the opportunity to gain relational rents in integrated supplier-buyer relationships on the one side and decreased flexibility on the other side has to be taken into account by an evaluation of the outcome of close relationships. The undifferentiated

“romantic” view on cooperation with suppliers neglects the possibility of flexibility reduction and performance weakness due to a lack of market pressure. However, if an integrated supplier-buyer relationship has to be changed, a professional and structured management approach is required in order to achieve a “smooth switch”.

In [19] the “focus is on the knowledge management challenges that come along with technology-based new business development (NBD). NBD thrives upon the exploration of knowledge, under radical uncertainty. Furthermore, existing knowledge may both enable and constrain the radical innovation process. These characteristics make the dominant approach of knowledge management – focusing on codifying, collecting and distributing knowledge – unsuited for NBD. We suggest that knowledge management can enhance NBD by focusing on experimenting, monitoring and integrating knowledge. [...] No individual is capable of learning everything that is necessary to develop and produce complex products. Individuals have restricted learning capacities [...]. The acquisition of knowledge requires that individuals specialize in specific areas of knowledge. Nevertheless, the development and production of complex products require the application of a wide range of knowledge [...] This fundamental asymmetry between knowledge acquisition and knowledge application has as a consequence that organizations have to integrate dispersed bits of specialized knowledge held by individuals” [19].

### **3.4. BASIC PARADIGM: “JUST-IN-TIME” SERVICE OR FAILED SERVICE**

The first search expression was “Bounded Rationality” + “Just-In-Time”, giving over 10,000 results. Since concept evolution was not a target anymore, the search could be focused successively on Google Scholar (since 2007) with 360 results. Since five results were from LBUS, to avoid the risk of “endogamic closure”, the scope was not narrowed further. Thus, “Just-In-Time” is explored as *response time* (3.4.1), as *agent-oriented mechanism* (3.4.2), i.e., as key mechanism to simplify the experimental model, and as *post-industrial variant of “real time”* (3.4.3).

#### **3.4.1. “Just-In-Time” As Response Time**

Ironically, the concept of “Just-in-Time” was born under a constellation of paradoxes, most of them seeming to be suicidal for the very concept.

From the two-echelon perspective mentioned in 2.3.3, the eleven paradoxes will be put in two (fuzzy confined) groups: the first is related to the general *shift from product to service* (2.3.3), and the second is focused on the evolution of the concept not only in relation to bounded rationality but focused on the strange *requirements of continuing education*. Thus, the order is a partial one in each group and shifting from the first to the second is a continuous move rather than an abrupt conversion:

a) Sugimori and the other inventors of the “kanban system” [158] intended to optimize the Toyota production system, while JIT was the seed of accepting that optimization is obsolete in real-world problems.

b) JIT production as “inventory-management strategy developed by the American au-

tomotive industry” realised that stating the problem in line with its original idea (“According to Ohno, inventory is waste that costs the company money” [50]) monocriterial optimization problem would be absurd. Indeed, at “Toyota’s production of over 15,000 cars a day” [71], a nil inventory was unthinkable.

c) Of course, it was defined as multicriterial optimization problem: JIT is about “providing the right material, in the right amount, at the right time, and in the right place” [50]. “On-time delivery is also a great source of reputation for quality and benefits from parallel movements such as Just-In-Time and so on. [...] On account of their much vaunted just-in-time inventory system, the company maintained only three days of stock, while a new factory would take six months to build” [71]. Only soon after it became obvious that any attempt to avoid bounded rationality – sticking to optimization as business mechanism – is prone to fail.

d) Moreover, the “kanban system” was dedicated to the epitome of the industrial era – the car industry – spawning even the term “Toyotism” [109] to replace the ancient “Fordism” – but was the kernel of the post-industrial era. In fact, JIT was service oriented from its very beginning as “information tag” letting know that a new product can be produced (JIT). The evidence is given by the etymology of the Japanese word “kanban”: “Kanban is a visual signal that’s used to trigger an action. Roughly translated, it means “card you can see” [<http://whatis.techtarget.com/definition/kanban.html>].

e) Much more wide-ranging, even as Zeitgeist component JIT is somehow self-contradictory. For instance, Virilio’s “logic of speed” (that shapes his dromology), is powerfully expressed nowadays through broad-band technology *because* of the context created by Moore’s law. However, the three day Toyota inventory represented a rather *festina lente* strategy, *because* it is multicriterial and boundedly rational. [7]

f) The next paradox is very telling since it has also linguistic roots: a “Just-in-Time service” sounds more and more pleonastic. Bizarrely enough, it replaces another anachronistic expression: “Real time programming”. The subliminal message is twofold: time is inexorably linked to the nature of (nontrivial) services; software should be based on processes not on programs (at least to be able to implement agent reactivity – no service provider could survive without reacting “Just-in-Time” to client requirements in ODUE [89], [142], [165]).

g) Despite the obvious fact that JIT delivery is decisive for any quality assessment of service providing, the value of a service is still elusive and highly subjective. Hence, a service-oriented approach to quality management is both unavoidable and challenging [68].

h) What is more, the field of learning – where “Just-in-Time” service is a *sine qua non* constraint – is a highly relevant example of how challenging could be any attempt to define this concept. Even more, when continuing education enters the arena, *teaching* and *learning* become mixed in a postmodern phenomenologic autopoietic adventure that impairs severely any objective assessment. “From the time adult education emerged as a field of study, it has suffered a crisis of identity by which the field is increasingly defined by a lack of consensus regarding its larger aspirations and operational boundaries. The purpose of this article is to begin deconstructing and reconstructing the field of adult

education phenomenologically by (a) exploring the basic historical assumptions and socially constructed, collectivist realities on which adult education founded its theory and practice in the modern era, (b) elucidating the postmodern turn these realities have taken in the past half century, and (c) reconciling adult education's historical mission with new realities facing the field. This article ultimately concludes that any viable conception of adult education must not only make postmodern individuals better competitors in the global marketplace, but must also help them and the organizations they comprise to define themselves within a larger autopoietic web of relations" [69].

i) The paradox is aggravated in engineering education where the switch from *static* to *dynamic knowledge* (i.e., to *skills*) is both urgent and hard to outline [66]. "Technical competence alone is not sufficient; an excellent chef plus an incompetent waiter gets a bad review. Employability and key skills are often addressed by the provision of one module that specifically targets these issues but in isolation to discipline content. Such 'professional engineering', or similarly titled, modules can pay lip service to the wide and complex range of non-technical skills and continue to isolate technical and non-technical competences as if they are mutually exclusive and should be split apart. This does not reflect the real world. [...] In contrast, student-centred approaches pay more attention to the learner's needs and abilities, achieve higher levels of engagement and thinking [...] and require the concurrent development of technical and non-technical knowledge and skills. Student-centred approaches include problem-based learning (PBL), [...] enquiry learning, discovery learning, case-based teaching and just-in-time teaching" [34].

j) Focusing on CSIT, a new time-related paradox emerges: atemporal, conventional mathematics-based education becomes unbearable – simply because atemporal services are out of the question in real-world settings. "More *Time* Is Needed" [67] in both hypostases as resource (preemptive in structure, non-preemptive in architecture).

k) Finally, the apex of all aporetic situations comes out in lifelong learning: the temporal hiatus between (present) e-teacher and (future) e-learner. [64], [5]. An interesting stance regarding learning opportunities is given in [1]: "Just-In-Time principles include swift reactions to market or technology variations and process monitoring to improve the end product [...]. For at least two decades, politicians, academics and other stakeholders have advocated cooperation across sectors, administrative layers and other institutionalised boundaries to achieve objectives of what are called 'learning regions' and the 'lifelong learning perspective'. Boundaries between geographical, institutional and sectors are becoming more porous. Regions and cities may be seen as complex adaptive systems, and hence do not necessarily follow the logic of formal institutions. While formal institutions have innate interests in regulating interaction and communication between their members, networks develop according to evolutionary or selectionist dynamics, in that the processes of change can be seen as analogous to natural (Darwinian) selection."

In short, if a State-of-the-Art section can be presented as a sequence of eleven paradoxes, this very fact is a relevant "kanban substantiation" that a major paradigm shift is needed "Just-in-Time" – here JIT is almost synonymous with "badly".

### 3.4.2. “Just-In-Time” As Agent-Oriented Mechanism

Here the magnifier is again implementation-oriented exploring JIT as lever to exploit BR in mechanisms (6.2, 6.3).

Some of the problems related to “Just-in-Time” are addressed in a “virtual teamwork spirit” from an organizational research stance covering the ICT domain (namely, *IT* plus Communication), in a book [70].

[2], considering “Just-in-Time (JIT) production [...] an inventory-management strategy”, “examines how innovative business practices are developed, diffuse across organizations, and effect industry-level change. Applying evolutionary economics and evolutionary organizational theory as a theoretical lens, it conceptualizes the adoption and diffusion of innovations as a dynamic process whereby innovations propagate vertically within firms via successive instantiations (or generations) as well as horizontally across firms via imitation and replication. Innovations that describe observable, transparent, and transferable business practices are the specific concern. Examples from management, software development, and e-commerce support the theoretical analysis. A two-level study, based on a formal stochastic process model, examines how innovations arise, which innovations do or do not survive in the market, and whether and under what conditions best practices emerge and industry standardization is achieved” [2].

[85] studies the “coevolution of academic research and industry practice” in the car industry: “the interrelation between adoption of modern management practices and organizational strategies adopted by firms. Such strategies correspond with the type of management practices available for firms, and shape the environment in which learning takes place [...]”.

[76] applies JIT in “human resource management and learning for innovation”: “In the case of pharmaceutical firms, and in the context of Good Manufacturing Practices (GMPs), 5 total-quality-management (TQM) and just-in-time (JIT) practices assist in meeting the strict quality controls required by regulatory authorities” [76].

A most specific context for JIT is in [51]: “serendipity in robbery target selection”. “Conventional wisdom also holds that ‘bounded rationality’ is especially problematic in high-velocity, uncertain environments imbued with desperation (such as street culture)” [51].

### 3.4.3. “Just-In-Time” As Post-Industrial Variant of “Real Time”

Here the magnifier is teaching-oriented, i.e., “Just-in-Time” being seen as cardinal architectonic feature. From a slightly different perspective “Just-In-Time” is seen as main current connotation of “real time”, reflecting the shift from product to service, crucial for the thesis setting (2.3.3, 3.4.1). Thus, research regarding learning based on BR is investigated too because of some very down-to-earth consequences – for the whole research cluster related to EU2020 – of the paradox constellation revealed below: a) it cannot be dissociated from “Just-In-Time” as response time; b) it could be considered only after the implementation of the experimental model; c) it concerns not just this thesis but equally also other two EU2020 theses (3.1.1) where it achieves another vital – and still paradoxical – connotation: continuing education involves a “JIT synchronization” between (*present*) e-



*teacher and (future) e-learner.*

[51] investigates JIT in IT settings: “While mistakes, and approaches to design and training that reduce them, have been studied extensively, relatively little work in HCI studies ‘slip’ errors, which occur when one intends to do a certain action during a skilled task but unintentionally does another. [...W]e examine approaches to training that might reduce the occurrence of a slip error referred to as a ‘device initialization error’. This error occurs when skilled users of a device forget to perform some initialization action, such as positioning the cursor in a text entry box or setting the device into the correct mode, before entering data or performing some other significant activity. We report on an experiment studying the effects of two training interventions on this error, which aim to manipulate the salience of the error-prone action without making any physical changes to the device. [...] Only participants who were asked to ‘test’ the device and also given enhanced instructions to enter dummy data after completing initialization actions showed a statistically significant improvement in performance”.

[82] studies JIT in bank management, via “learning by example: imitation and innovation” showing that “network, cognitive, and institutional perspectives provide interlocking accounts” and that the “treatment of mimetic isomorphism is grounded in Cyert and March's (1963) analysis of bounded rationality and problem-driven search”.

After all, serendipity illustrated itself in a most fascinating, transdisciplinary, while still strongly thesis-related manner as the term proposed to translate “Just-in-Time” for the Romanian abstract of this thesis (7.4.3).

### **3.5. EXPERIMENTAL MODEL DOMAIN**

The implicit search keywords for this section, “bounded rationality” + “visual pattern recognition”, revealed 13.000 results, containing rather coincidental occurrences than significant information. (Hence, the architectonic novelty of the experimental model domain is clearly determined.) Thus, the few valid information applicable after filtering refer to *compression* and *benchmarks* (3.5.1). However, to add a “RB-touch” to a very compressed “LB story” the chapter ends with some old news about *Lena as “Information Age Madonna”* (3.5.2).

#### **3.5.1. Compression and Benchmarks**

By narrowing the search to “just in time” “tailored transmission” the result was the expected one: until now “image transmission” and JIT had no conceptual relationship.

In the field of visual information, transmission and storage are closely tied together, because of the need for compression. The purpose of image compression is to represent images with less data in order to save storage costs (in the XX-th century) or transmission time (always) [[http://en.wikipedia.org/wiki/Image\\_compression](http://en.wikipedia.org/wiki/Image_compression)]. Relevant technical updates are in [145], [86], [84]. Roughly, these techniques are split into *lossless* or *lossy* versions. Both – even if lossy compression is usually based on techniques for removing details that humans typically don’t notice – still transfers the image as a whole, unaware of *semantic content* or *user-tailored* “JIT” transmission.

*Conventional Benchmarks.* According to Merriam-Webster, the connotations of benchmark appropriate to this thesis are: “something that serves as a standard by which others may be measured or judged, [...]: a standardized problem or test that serves as a basis for evaluation or comparison (as of computer system performance)”. In line with a leitmotif of exploratory research in engineering – for those mathematicians who accept its existence – it is crucial to have at hand a strong specimen in the application domain. Therefore, judging the outcomes of this thesis in the light of the new approach it contains, means finding an undisputable and well-liked benchmark to measure with is mandatory.

In the field of the model, conventional benchmarks are test images widely used in digital image compression/transmission and generally in image processing and computer vision. The most famous one is presented below.

### **3.5.2. Lena as “Information Age Madonna”**

Some of the standard test images that have reached cult status over time are known as Lena, Pepper, Baboon (aka. Mandrill), Barbara, Zelda, Airplane, Photographer, Lighthouse, Boat. These images are still present in recent research and keep on their status of benchmark [86], [84], [55].

As the history abridged below shows, the Lena picture is one of the most widely used standard test images for compression techniques. Actually, it is a digitized image of the Swedish model, Lena Sjööblom, from 1973. The picture was scanned at the University of Southern California (USC) for their image processing research [154] – work that would lay the foundation for the JPEG [140] and MPEG [161] compression standards. The original version was produced by a scanner with fixed resolution of 100 lines per inch but the engineers wanted a 512 x 512 image, so they limited the scan to the top of the picture, effectively cropping it at the subject's shoulders. The initial scan is still available as reference in the USC Signal and Image Processing Institute Image Database, “maintained primarily to support research in image processing, image analysis, and machine vision” [154].

Early in its history, the image became a widely and quickly accepted standard: “Visitors asked us for copies, and we gave it to them so they could compare their image processing and compression algorithms with ours on the same test image” [160], [136]. In [147] are mentioned two obvious reasons for Lena’s success: “I think it is safe to assume that the Lena image became a standard in our “industry” for two reasons. First, the image contains a nice mixture of detail, flat regions, shading, and texture that do a good job of testing various image processing algorithms. It is a good test image! Second, the Lena image is a picture of an attractive woman. It is not surprising that the (mostly male) image processing research community gravitated toward an image that they found attractive” [147]. A detailed history of the Lena image as “Information Age Madonna” is in [136]: “most people in the field seem to believe that Lena has served well as a standard. She is like ... a familiar reference that helps an audience of insiders make ready judgments” and concludes “surely, no image since Mona Lisa has been studied harder” [136].

Thus, because of the wide popularity of the Lena picture, it is – if not mandatory – at least very wise to choose Lena as benchmark.

## FOURTH CHAPTER

### The Meteoric Rise of “Bounded Rationality”. Its New Role

*The logic of reality triumphs over the logic of theory*  
WELLS "A short history of the world"

The baroque title insinuates a long preterminologic existence as an “incognito voyage” and hence encourages a chronological approach, investigating the evolution of the very concept of BR from hindrance to excuse, to mechanism, to strategy, in line with the holistic approach the EU2020 theses are based on. Thus, “meteoric rise” should not be disambiguated since it suggests – besides an impressive evolution – Haeckel’s recapitulation theory (see 7.4.3). Accordingly, the conceptual rise is split into *three eras*: *Pre-Simonian* (4.1, characterized by preterminological syncretism), *Terminological* (4.2, focused on the possibility of proper human decision making) and *Post-Industrial* (4.3, focused on fighting chaoplexity).

#### 4.1. PRE-SIMONIAN ERA. BEST VERSUS SIMPLE

“Don’t plan anything in detail” is not an advice from a guru of Economics, but a constituent of a Viking law (i.e., “Be brave and aggressive” [<http://www.facebook.com/group.php?gid=147344168610982>]) revealing three facts: a) BR has a long-standing and significant pre-Simonian use; b) it was organically related to another unborn concept: “Just-in-Time” (even for ancient people time was to valuable an asset to be spent on optimizing); c) it was not a purpose for itself, but an ingredient of a holistic endeavour. On the other hand, during its half a century long terminological life (namely, *after* the Simonian description) the concept underwent various transformations, acquiring several new connotations – some basic ones due to psychologists, as illustrated in the “State of the Art” above, including the ambivalence of BR in education and the holistic approach underlined. Therefore, the preterminological life of BR shows its intrinsic anthropogenetic/psychological nature, unavoidable because of the vital need to manage situations “Just-in-Time”.

##### 4.1.1. Why Is “Best” Antagonistic to “Simple”?

“Scientific terms may be roughly divided into two categories: those that are introduced by means of a precise [...] definition [...] and those that are drawn from everyday language and which have further to travel before they attain the status of an unequivocal definition. The word “complexity” [...] belongs to the second category and is particularly resistant to precise definition. This is also because it is often confused with the word “complication” [...] and because both terms are mostly used to mean the opposite of “simple” [138]. Thus, “simple” should be understood here (only) from an epistemic stance, meaning “easy to grasp”. The other conceptual pillar, “best” means “most favorable, advantageous, desira-

ble; surpassing all others” [<http://www.thefreedictionary.com/{best, optimum, optimal}>], hence *optimization* – much stronger than *improvement* – was from the very beginning rarely monocriterial and almost always contextual. Thus, the two concepts started a “chaoplex relationship”.

The deep psychological divergence between “best” and “simple” – illustrating the ambivalence of BR – is noticeable in the way the Aesthetic canons were dealt with in the classic period of visual arts: they were both normative (it is simple to obey a given rule, believing that it is “perfect”) AND flexible (when the Zeitgeist changed, it became simpler to feel free to be creative, forgetting about cumbersome rules). Though, there are just apparently two opposite meanings of canon. Indeed, the only problem is to find out what is easier in a given moment? Sticking to the “old best” but learning all its details or getting rid of it and inventing a “new best” (positive feedback reacting to changes in the environment)?

Hence “simple” was paramount, whereas “best” became arguable (in 5.2 such incongruities are lessened). The trouble started when mathematics rose from an essential intellectual and pragmatic endeavour based on palatable concepts expressed via common words (e.g., integers or fractions) to a scientific-esoteric religion where words are too simple to express real-world concepts, whereas “best” is disconnected from “good” (hence, “better” is confusing) being defined dogmatically, based on numbers: stiff, atemporal, Manichaeic – hence bewildering.

#### **4.1.2. Some Lessons from the Prehistory of Optimization**

Dido/Elissa “according to ancient [...] sources, the founder and first Queen of Carthage [...] best known from Virgil's Aeneid [...] asked [...] for a small bit of land for a temporary refuge [...] only as much land as could be encompassed by an oxhide. [...] Elissa cut the oxhide into fine strips so that she had enough to encircle an entire nearby hill [...]. This event is commemorated in modern mathematics: The “isoperimetric problem” [...] often called the “Dido Problem” in modern Calculus of variations” [[http://en.wikipedia.org/wiki/Dido\\_\(Queen\\_of\\_Carthage\)](http://en.wikipedia.org/wiki/Dido_(Queen_of_Carthage))]. Thus, the first optimisation problem was the isoperimetric problem of enclosing the maximum area within a fixed perimeter and was solved in three steps (in IT jargon they could be seen as: system analysis, performance metrics, finding a function extremum). “The subject of isoperimetry has a long and eventful history, both for its impact on people's imaginations and society in general and for the impetus it has given to the study of various mathematical subjects. [...] If one assumes a straight coastline, then the answer, which was by all appearances discovered by Queen Dido, is to lay down the hide in the shape of a semi-circle. One finds the problem of Queen Dido colorfully described, including various embellishments of the basic problem, in the expository account that Lord Kelvin gave in 1893” [3]. This quotation from a comprehensive Dido problem history conveys three – subliminal but cardinal messages: a) It is an old mathematical and philosophic memplex (although the Greeks knew that the solution is a circle, the first rigorous proof was given only in the 19th century, long after seminal work of great mathematicians such as Euclid, Al-Kindi, Leibnitz and Newton). b) It highlights the pervasive propension towards “optimising optimisation”. c) Likewise, it suggests another longlasting propension: the

Kelvinian obsession with precise measurements as axis for scientific advancement [35], [12], [64] (see also 3.4).

### 4.1.3. Simple Is Looked For

The archetypal instance of this heuristic rule is Occam's Razor, "*Lex parsimoniae*": "Prior to the 20th century, it was a commonly-held belief that nature itself was simple and that simpler hypotheses about nature were thus more likely to be true [...]. Simon argued that whether something is simple or complex depends on the way we choose to describe it [...] In physics, parsimony was an important heuristic in the formulation of special relativity by Albert Einstein, [...], the development and application of the principle of least action by Pierre Louis Maupertuis and Leonhard Euler, [...] and the development of quantum mechanics. [...] In chemistry, Occam's razor is often an important heuristic when developing a model of a reaction mechanism [...] Karl Popper argues that a preference for simple theories need not appeal to practical or aesthetic considerations. Our preference for simplicity may be justified by its falsifiability criterion: We prefer simpler theories to more complex ones "because their empirical content is greater; and because they are better testable"" [[http://en.wikipedia.org/wiki/Occam's\\_razor](http://en.wikipedia.org/wiki/Occam's_razor)].

Other instances: Dennett's "intentional stance", thumbnail rules, educated guess, toy-problem modelling. (They are not elaborated upon here, because they are used as main tools in [26].)

## 4.2. TERMINOLOGICAL ERA. IS PROPER DECISION MAKING ACHIEVABLE?

The question defines the era. What is much more, Simon *invented* the era by *defining* the term. Trying an answer, BR is looked for in *decision making* itself (4.2.1) as well as in its target application domain, *behavioural economics* (4.2.2). On this groundwork BR is examined within its relationship to *approximation* (4.2.3), to *uncertainty* (4.2.4) and to a *post-industrial theory of value?* (4.2.5). Though, as shown in 2.3 the thesis' main two conceptual pillars coexisted in this era for decades. Therefore, an investigation about their relationship should be expected as "4.2.6. Bounded Rationality and "Just-in-Time"". From a subjective, "*intentio auctoris*" stance, its unfeasibility explains what this thesis is all about.

### 4.2.1. Bounded Rationality and Decision Making

"The research program of bounded rationality is built on three premises: (a) humans are cognitively constrained; (b) these constraints impact decision making; and (c) difficult problems reveal the constraints and highlight their significance. Thus, strategies may be optimal in easy domains (e.g., tic-tac-toe) but suboptimal in hard ones (e.g., chess). Understanding the most important mental constraints, such as selective attention and limited working memory, helps explain why people use certain kinds of heuristics (i.e., rules of thumb) in hard domains, hence why and how performance is suboptimal. However, the Simonian branch of this research program emphasizes why many highly trained specialists

manage to perform relatively well despite working under these universal cognitive limitations. By contrast, the Tversky-Kahneman branch focuses more on errors made by everyone, experts and novices alike. Theories of bounded rationality have been applied to diverse political contexts such as elections and budgeting” [101].

“It is said that Herbert Simon would have described himself as follows: *“I am a monomaniac. What I am a monomaniac about is decision making”*. [...BR] was a conceptual weapon against the “optimization” school which dominated the decision paradigm. Thus “bounded rationality” was a refutation of all the classic hypotheses of optimal choice: perfect knowledge of alternatives and consequences, perfect preferences between consequences and so on. But if Simon was critical to maximization theories, he persistently understood the concept of rationality through one specific operationalization: an empirically grounded theory of human problem solving. [...] Simon also proposed to build such theory of decision making and problem solving on a « satisficing » principle. This principle introduces subjectivity, “rules of thumb”, heuristics or ad hoc moves as basic decision making processes. *For sure, there can be no universal “satisficing” principle or it would appear as a new form of “optimization”*” [132].

#### **4.2.2. Bounded Rationality and Behavioural Economics**

Unfortunately, in (behavioural) economics BR is still considered just as a hindrance, not as a means to manage situations “Just-in-Time”. Thus, Santos [77] talks about “problems caused by incomplete information, bounded rationality and weak willpower” and about “providing individuals with the required information and on suggesting various devices that can help them to make the right calculations, thereby preventing the detrimental effects of the bounded rationality of homo sapiens”. (No mention about the time required for such “right calculations” with the help of “various devices”.) Likewise, [31] increases the confusion: “what economists call ‘satisficing’ or ‘bounded rationality,’ where decisions or choices are made in the absence of complete information”. (Clearly, the balance needed to be redressed, revisiting in detail the potential of this misunderstood concept. Moreover, it becomes obvious that in real-world applications, there is no BR separated from “Just-in-Time”, instead they represent somehow dual aspects of the most natural strategy of managing situations.)

“From his early papers on administrative behaviour to his last investigations on thought and learning, Simon kept a same goal: to explain complex and mysterious human behaviour by simple and constrained, yet informed decision rules. [...] But beyond this critical aim, Simon attempted to build an empirically grounded theory of human problem solving” [132]. (Since the axis of the EU2020 research is education, the emphasis is on the key role of obtaining results “Just-in-Time” for both participants – teacher and learner – rather than on explaining why decision making – first of all in economic problems – is far from being easy to defend.)

### 4.2.3. Bounded Rationality and Approximation

Instead of optimization, the main mathematical mechanism able to save time in boundedly rational contexts is *approximation*. From the thesis perspective it was investigated in [13]: “Starting from the premise that [...] most non-trivial IT applications are meant for and hosted by open, dynamic, and uncertain environments the paper aims at: a) showing that both *bounded rationality* and *approximation* are, at the same time, unavoidable *restrictions* and valuable *means* when developing such applications; b) underlining the inadequacy of conventional mathematical methods [...]; c) outlining an agent-oriented approach to combine synergistically *bounded rationality* with *approximation* in modelling. [...] Among the conclusions: approximation theory has still a major role to play in artificial intelligence but mainly aiming to achieve synergy via blending it with bounded rationality (based on the “Just-in-Time” paradigm), not as instrument for uncertain knowledge processing, because of its atemporality (mainly its incapacity to deal with future events); on the contrary, the approach proposed here allows a better reaction to uncertain and rapidly changing environments (it keeps open alternatives)”. As regards the concept of approximation “Definitions on the Web: “estimate: an approximate calculation of quantity or degree or worth”; “the quality of coming near to identity (especially close in quantity)” (wordnet.princeton.edu/perl/webwn); “inexact representation of something that is still close enough to be useful. Although approximation is most often applied to numbers, it is also frequently applied to [...] mathematical functions, shapes, and physical laws.” (en.wikipedia.org/wiki/Approximation). These definitions (firstly the last one) are relevant as regards: a) both the commonsensical and the scientific (mainly, mathematical) meanings of approximation; b) its role as degree of uncertainty (as “measure” of: imprecision, difference between a reported value and a real value, possible error or range of error, etc.); c) its major function as optimisation tool. [...] [S]ome relevant connotations could be suggested by the antonym of “approximate”: “Exact” means “marked by strict and particular and complete accordance with fact; accurate: (of ideas, images, representations, expressions) characterized by perfect conformity to fact or truth; strictly correct;” (<http://wordnet.princeton.edu/perl/webwn?s=exact>). [...] [S]ome relict prejudices are still strong: most mathematicians make believe that only quantifiable and predictable aspects are worth to be explored; worse, they use old-fashioned informatics to impose this conviction. (UML-based modelling is just one of the constraining tools.) Moreover, the situation is unchanged, despite the over ten years since Zadeh reasserted the roles of fuzzy logic and soft computing from an undisputable mathematical stance [87]” [13].

### 4.2.4. Bounded Rationality and Uncertainty

Here uncertainty is seen as the epistemic facet of nondeterminism [93]: for decision making it doesn’t matter whether information is incomplete because the effects of an event are yet ignored or whether the event still not happened (future contingents).

Ignoring the fact that bounded rationality is “a form of behaviour associated with uncertainty where individuals do not examine every possible option open to them” [[www.pest-management.co.uk/lib/glossary/glossary\\_b.shtml](http://www.pest-management.co.uk/lib/glossary/glossary_b.shtml)], the mathematical tools still recom-

mended for modelling processes taking place in OHDUE (approximation theory included), are ill-applied when they try to deal with uncertainty” [13].

“Human intelligence [...] is modelled by an adaptive toolbox that contains building blocks for heuristics to direct search for information, to stop search, and to make a decision. Smart search rules describe how people find the few relevant pieces of information, in memory or in the outside world. Stopping rules describe a primary function of cognition, to ignore or discard irrelevant information. Decision rules translate the information searched in memory or in the outside world into behaviour, such as what profession to choose or what products to buy. The adaptive toolbox embodies an ecological, not logical, view of rational behaviour. The building blocks can be recombined to form new heuristics, which are rational to the degree that they are adapted to the structure of environments in which they are employed” [152]. (In line with the above, in this thesis, the first – very bounded – agent-oriented software will be considered applying heuristics similar to those used by a tired person when looking for the misplaced eyeglasses.)

#### **4.2.5. Bounded Rationality and a Post-Industrial Theory of Value?**

This section was added very late (October 2011) because the quotes that follow show that: a) existing theories of value are deficient; b) the reasons are known and commonly accepted (from increasing complexity and speed of change, to incomplete information and poor modelling); c) despite being written a few years after Kahneman received the Nobel Prize (3.3.1, 4.2.1 [141]), they don't refer to BR (just, “random acts of impulse” may suggest it vaguely); d) post-industrial society or service-oriented economy are not referred to either.

“Any attempt to model an economy requires foundational assumptions about the relations between prices, values and the distribution of wealth. These assumptions exert a profound influence over the results of any model. Unfortunately, there are few areas in economics as vexed as the theory of value. [T]he fundamental problem with past theories of value is that it is simply not possible to model the determination of value, the formation of prices and the distribution of income in a real economy with analytic mathematical models. All such attempts leave out crucial processes or make unrealistic assumptions which significantly affect the results. There have been two primary approaches to the theory of value. The first, associated with classical economists such as Ricardo and Marx were substance theories of value, which view value as a substance inherent in an object and which is conserved in exchange. For Marxists, the value of a commodity derives solely from the value of the labour power used to produce it [...]. The labour theory of value has been discredited because of its assumption that labour was the only ‘factor’ that contributed to the creation of value, and because of its fundamentally circular argument. Neoclassical theorists argued that price was identical with value and was determined purely by the interaction of supply and demand. Value then, was completely subjective. Returns to labour (wages) and capital (profits) were determined solely by their marginal contribution to production, so that each factor received its just reward by definition. Problems with the neoclassical approach include [...], perfect competition, perfect and costless information and contract enforcement, complete markets for credit and risk, [...],



and perfectly rational agents with infinite computational capacity. Two critical areas include firstly, the underappreciated Sonnenschein-Mantel-Debreu results which showed that the foundational assumptions of the Walrasian general-equilibrium model imply arbitrary excess demand functions [...]. Secondly, in real economies, there is no equilibrium, only continuous change. Equilibrium is never reached because of constant changes in preferences [...]; technological and organisational innovations; [...]; the entry and exit of firms; the birth, learning, and death of citizens; changes in laws and government policies; imperfect information; [...] random acts of impulse; weather and climate events [...], and so on. The problem is not the use of mathematical modelling, but the kind of mathematical modelling used” [151].

“Knowledge is implicitly assumed to form an increasingly important, or even the dominant source of values for today’s knowledge based organizations. It is rare, however, to encounter writings questioning what is ‘value’, enquiring into its provenance, or examining its distribution amongst organization’s stakeholders. This chapter asks these very questions, focusing on Marx’s [...] formulation of value theory. [I]t begins by giving a basic overview of the labour theory of value, as developed by Marx in mid-19th century, industrialised England. The second part examines Roy Jacques’ [...] critique of Marx, his rejection of the adequacy of ‘labour’ as a concept for analysing contemporary value production, and his call for a ‘knowledge theory of value’” [23].

Lacking the very need of a theory of value in line with the new paradigms – in economics, management, IT and so on – substantiates the question mark in the section title.

### **4.3. THE POST-INDUSTRIAL ERA? FIGHTING CHAOPLEXITY**

Why the question mark? Because: a) Post-industrial era is not yet conceptually established. b) Cognitive chaoplexity neither. c). There is a double (biased) perspective: for the EU2020 research the focus should be on the aim, whereas for this thesis the focus is on BR as means. d). Even considering only “conventional complexity” the problem is fuzzily related to the second and third objectives. (Hence, most quotations stem from previous CSITAO research.) Anyhow, as suggested above (4.2.3, 4.2.4) there are two kinds chaoplexity to be fought: *unavoidable* (because of *cognitive* boundaries, 4.3.1) and *avoidable* (via further investigation, 4.3.2).

#### **4.3.1. Unavoidable (Cognitive) Complexity**

“Present-day IT environments [...] move fast from limited, homogeneous, changing slowly, deterministic (even if partly approximated or even unknown) towards open, heterogeneous, dynamic, and uncertain environments (OHDUE). That means [...] intrinsically non-deterministic – as most environmental and almost all human stimuli generators. Among the context-related reasons: globalization, modern enterprise paradigms [...], intense (mainly positive) feedback. The main IT-related reason is Moore’s law and its most vigorous consequences” [13].

In medical settings “The inability to understand statistical information is not a mental deficiency of doctors or patients but is largely due to the poor presentation of the information [...]. For each confusing representation there is at least one alternative, such as natural frequency statements, which always specify a reference class and therefore avoid confusion, fostering insight” [127]. Likewise, “The problem is neither to admit that for any medical act (and for even stronger reasons as regards nursing) “Just-in-Time” is a *sine qua non* condition, nor that bounded rationality is the only practical means to achieve it [127]. Nevertheless, there is a double hindrance, due to a yet prevalent mentality: a) therapeutic decision-making is an exclusively human attribute; b) non-algorithmic software is – if not nonsensical – applicable at most to toy problems. To challenge both prejudices, the approach must be based on microcontinuity and any nurse-patient interaction episode, similar to a learning process, should be assessed through a Simon-like performance metrics [...]. As a result, bounded rationality will not be just a design space dimension but a fascicle of interrelated, versatile, and highly application-dependent features. Any bounded rationality dimension must have aspects able to cover a wide range of values” [6].

#### 4.3.2. Avoidable (Black Box) Complexity

The problem of boosting ergonomics in decision making via BR was dealt with in [16]: Uncertainty as epistemic concept, together with its species and degrees, was investigated starting from the 28 definitions found on the Web. Besides the [...] diversity of those definitions, ranging from “doubt” to “statistically defined discrepancy”, the very meaning of uncertainty “depends on the professional background and on the task to carry out ([...] mostly on the time available to complete it)” [16]. To impair redundancy with 1.1.1, in short “*uncertain*” means practically for mathematicians, *unknowable*, for software developers, *undependable*, and for end users (decision-makers), *undecidable*. “In this context could be found a common denominator for a general definition of uncertainty – at least, acceptable to the three categories mentioned above? Uncertainty, in its widest sense, comprises any unsure link in the chain of steps necessary to fulfil a task” [16].

On the other hand, from the 28 definitions “only a few are interesting, since they are anthropocentric, mirroring the common user (mainly decision-maker) stance: a) “doubt” [...]; b) “the fundamental inability to make a deterministic prognosis” [...]; c) “lack of knowledge of future events”.”[17].

Unfortunately, AO mechanisms “have – beside lacking validation *in vivo* (some of them not even *in ovo*) – a double vulnerability: they are either incremental as regards the “Kelvin way of thinking” or too loosely linked to new paradigms. Thus, what is their relevance? To break the vicious circle – since there is no “methodology for paradigm shift” – to leave behind the 3rd Order Ignorance [90], software should be considered “not a product, but rather a medium for the storage of knowledge. [...] The other knowledge storage media being, in historical order: DNA, brains, hardware, and books. [...] Software development is not a product-producing activity, it is a knowledge-acquiring activity” [90] quoted in [35].

## FIFTH CHAPTER

### Transdisciplinary Communication Needs a Lingua Franca: GST

*The limits of my language signify the limits of my world*  
WITTGENSTEIN "Tractatus Logico-Philosophicus"

As shown in 2.2.1, this chapter is due to the double expansion of the first thesis objective (necessary to replace the conventional conceptual framework unsuitable to articulate the role of BR as *educational mechanism*): a) *Choosing a Lingua Franca* involves a *rationale* – as well as a *method* – of its own (5.1). b) *Expressing bounded rationality in terms of General System Theory* is carried out in three steps: In line with the even stronger emphasis on *holistic approaches* (as regards both BR and continuing education) the *Lingua Franca* is employed to elaborate on the relationship between *cognition* and (cybernetic, automatic, intentional) *systems* (5.2) and subsequently on the key – albeit ambivalent – role of *bounded rationality as feedback* (5.3). Shifting now the transdisciplinary focus from *psychology* to *semiotics*, *synergetics* – as a branch of General System Theory – is used to defend the fifth thesis objective, suggesting that when CSIT will eventually return to its (analog) sources in *search for synergy* it should head rather to *Lao Tzu* than to *Aristotle* (5.4).

#### 5.1. RATIONALE AND METHOD

It is self-explaining that transdisciplinary research needs a Carnap-like glossary (1.2.2). Of course, it is better when such a “mini-ontology” is contained in an established theory usable as *Lingua Franca*. However, why this language should be *GST* needs a motivation. The reasons are presented according to increasing specificity: the need for *GST as metascience* (5.1.1), followed by the reasons clustered under the relationship between *semantic web and general culture* (5.1.2).

##### 5.1.1. Post-Industrial (Holistic) Approaches Require GST as Metascience

Trying to adapt engineering education (EE) to the needs of a service-oriented society, [65] suggests “a way of easing paradigmatic shifts by instilling into syllabi metascience basics”. Below is abridged Subsection 6.3 of [65]:

“The hard to define term of metascience (most encyclopaedias, redirect to metaphysics) is used here pragmatically as umbrella term for several disciplines linked to General System Theory (GST), i.e. using “μετά” rather as “above” than in its original sense (“after”). Even looser, the umbrella covers all (established or syncretic) disciplines linked to the conceptions of von Bertalanffy and of Mario Bunge, mainly as regards:

- *Systemics* as “an initiative to study systems from a holistic point of view [...], an alternative paradigm for research related to general systems theory and systems science” [<http://en.wikipedia.org/wiki/Systemics>].

- *Epistemology* (vital for [...] EE is the distinction between "knowing that" and "knowing how", with epistemology primarily interested in the former" [<http://encyclopedia.thefreedictionary.com/epistemology>]).

- *Systems theory* as "interdisciplinary theory about the nature of complex systems [that, as said by von Bertalanffy,] "should be an important regulative device in science," to guard against superficial analogies that "are useless in science and harmful in their practical consequences" [[http://en.wikipedia.org/wiki/Systems\\_theory](http://en.wikipedia.org/wiki/Systems_theory)].)"

From the three metadisciplines above is selected the conceptual kernel of GST itself while some key concepts stem from disciplines with a relative stable corpus of knowledge like Cybernetics, Synergetics, Cognitive Science, or Complex adaptive systems" [65].

On this basis this thesis (and [26] even more) can expand the enquiry to *cognitive psychology* as a whole, formulating the needs of agent-orientation in terms of GST, not of Computer Science. Thus, it impairs parochial interpretations and becomes closer to an expected psychological perspective. Indeed, von Bertalanffy was biologist and was Fechner's student.

### 5.1.2. Semantic Web and General Culture

Other four reasons can be clustered under this "umbrella-title":

- *Semantic Web and semiotic endogamy*. One of the possible side-effect implication chains of modern IT is: Semantic Web → Social Networks → Folksonomies → Linguistic Closure. Taking into account Wittgenstein's caveat that the limits of our language are the limits of our world, GST, being an established and lasting Lingua Franca acting as "mini-ontology-Kernel", could diminish the danger, because it encourages semiosis based on holistic, transdisciplinary, and flexible approaches. It is time to remember that this new age was portrayed as "Projekt der Semiotisierung" [149], because as Nake asserted, IT is just "technological semiotics" (i.e., the relationship between IT and semiotics is the same as the relationship between electrotechnics and physics) [149], [148]. As regards the link to BR, "even conventional logic is often too complex for end-user bounded rationality: "the grounding of the Semantic Web in formal logic makes both the comprehension and production of ontological content difficult for many end-users [80]" [65].

- *General culture requires GST*. "Holism was a crucial Renaissance ideal" [65]. Now it manifests a remarkable "comeback as educational approach (the promises of the semantic web reshape it almost into a target) even in post-industrial EE" [65]. For the shift from static to dynamic knowledge (2.2.3, 3.4.1) GST is badly needed as both subject matter and approach. Indeed, even bright PhD students with Master's degree in Engineering ignore the meaning of "negative feedback" (worse, some of them consider that it must have "negative connotation", see 5.3.1). Thus, to lessen the claim, at least engineering education requires GST.

- *A fortiori, CSIT requires GST*. In the experimental syllabus for agent orientation proposed in [64], two consecutive courses are "5. General System Theory (conceptual kernel plus some key concepts from cybernetics, synergetics, cognitive science, complex adaptive systems). 6. Communication (Peirce's semiotic triad. Granularity, ambiguity, relevance.

Volume, speed, fidelity, secrecy. Languages: nontextual, nonverbal).” It is necessary but not at all sufficient, since no syllabus (electronics, computer science, physics, mathematics, and so on) links Barkhausen’s relation to general system (in)stability (5.3.2).

- *GST is sine qua non for heutagogic metalearning.* The self-recursive exercise in heutagogic metalearning [65] required elements of cybernetics for all CSITAO students and elements of the three metadisciplines mentioned in 5.1.1 for those involved in continuing education.

As regards the method of teaching GST, in line with the heutagogic exercise mentioned, it was direct, focused on the thesis objectives, as illustrated below.

## 5.2. HOLISTIC COGNITION IN GST TERMINOLOGY

An “acting premise” of the research within the whole EU2020 thesis cluster – shown explicitly or implied by the quotations regarding *cognitive science* and *cognitive psychology* is *Wa4*, now without any *caveat* parenthesis. As a result, here only the relationship between *cognition* and *educational systems* seen as *cybernetic* (5.2.1) and *intentional* (5.2.3) was a matter of interest and hence initially dealt with. However, to be more convincing as regards the paradigmatic shift towards *accepting two kinds of decision making* in a service-oriented society, the key features of *automatic systems* (5.2.2) were added. Likewise, the relationship between BR and the *Dennett Stances* (5.2.4) is worth deeper investigation.

### 5.2.1. Cybernetic Systems

To keep in line with the requirements of both transdisciplinarity and BR, the two parts of the syntagm “Cybernetic System” will be explained “as simple as possible but not simpler” – to cite Einstein’s deference to yet syncretic BR.

- *System.* “A system is a set of elements and relationships which are different from relationships of the set or its elements to other elements or sets” [<http://en.wikipedia.org/wiki/System>]. However, in GST the concept was refined: “Von Bertalanffy's objective was to bring together under one heading the organism science that he had observed in his work as a biologist. His desire was to use the word "system" to describe those principles which are common to systems in general. In GST, he writes: "there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or "forces" between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general” [[http://en.wikipedia.org/wiki/General\\_System\\_Theory#General\\_systems\\_research\\_and\\_systems\\_inquiry](http://en.wikipedia.org/wiki/General_System_Theory#General_systems_research_and_systems_inquiry)].

Within the EU2020 cluster, the simplest instance of an educational system is represented by the classical pair: a teacher and a learner. (In the seventh chapter they will be prefixed with “e-“.)

- *Cybernetic.* A system is called “cybernetic” if it is able to tune its input via “feeding back” information from its output. In the case of the simple system (referred to by default in

this thesis), that means that *the teacher can tune* its teaching according to a *performance metrics* applied when *examining the learner's results* (4.3).

### 5.2.2. Automatic Systems

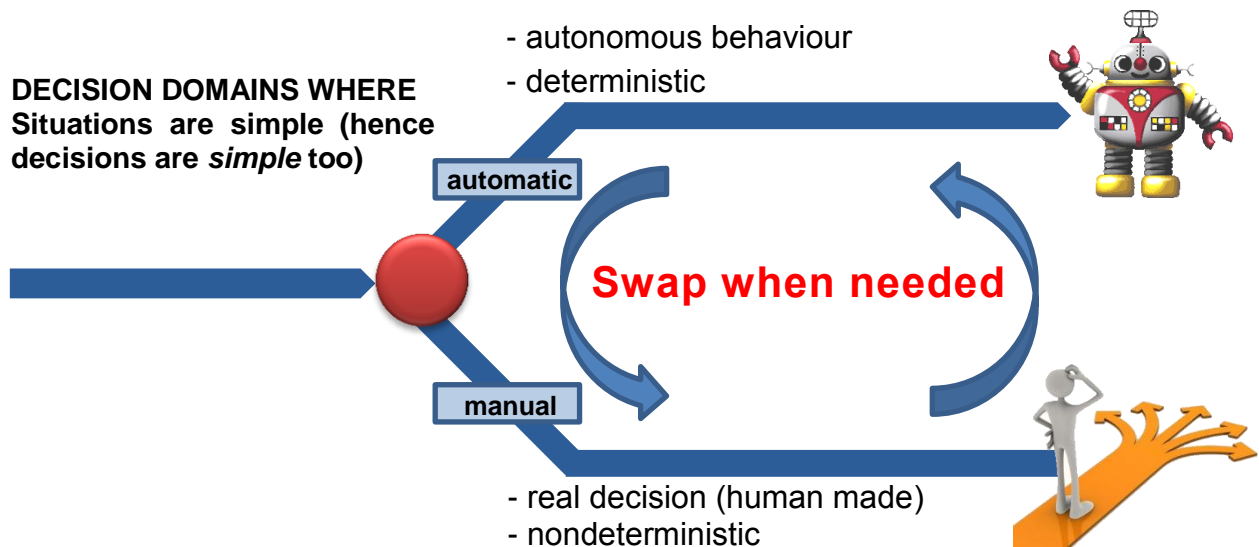
Of course, it is neither conceivable nor legitimate to change whatsoever regarding the connotations of any concept, or paradigm, or method applied in Control Engineering. Here it is about *divergent* paradigms. Hence it is (mostly?) about *language*.

It is obvious what “Automatic control” means but when “control” is used separately in its usual – and ordinary, primary – meaning (in GST terms, related rather to *negative feedback* and to *redundancy* than to *initiative* or *dominance* or *authority*) communication is impaired. (Indeed, Ctesibius' clepsydra is referred to even nowadays as precursor of Control Engineering although it *measures* time without being able to *control* it!)

Some debatable examples of unclear but important questions: “Does a robot have *initiative* when it is *in control*?” “Does *autonomous behaviour* imply *initiative* or *control*?” “Does it imply *both* or *none* of them?” Answers are totally outside the scope of CSITAO (its glossary [14] included).

Nonetheless, researchers in Control Engineering are indispensable to transdisciplinary CSITAO research. Thus, to enable cooperation before proposing non-algorithmic mechanisms in 6.2 and 6.3 the CSITAO perspective is (re)asserted in 6.1 mainly as regards the only (yet major) difficulty:

This thesis claims that in complex situations, human decision makers need a paradigm shift based on BR *because* they must make decisions “Just-in-Time”. Some aspects of this “paradigm-shift-problem” are illustrated in Figure 5.1.



**Figure 5.1.** From simple to complex ... but “Just-in-Time”

As underlined in 2.4.2, a main principle of “anthropocentric design” states that the interface complexity should be the burden of the system, not of the user. As a result: anthropo-

centric systems “must work more and more in an autonomous way. There are three main sources autonomous behaviour stems from: living beings, automata, and software” [10].

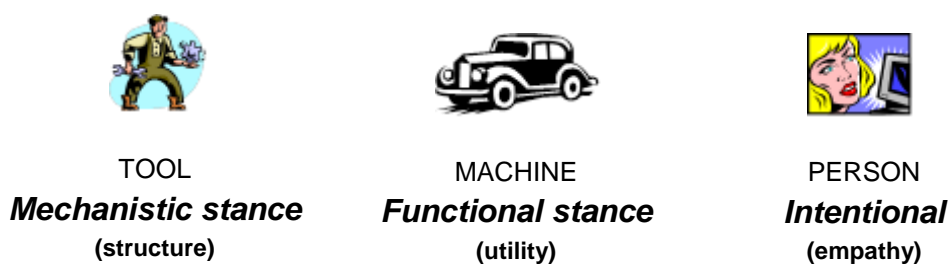
### 5.2.3. Intentional Systems

As regards *intentionality* simplicity is impossible, since for living entities the feature is trivial, while for (bodiless) agents asserting it gets close to blasphemy. The explanation that follows is taken from a book written from an unmistakable user perspective [96]: “To talk about the intelligence or the intentions of an artificial entity seems absurd for some people, dangerous for others, immoral for most – hence, unfortunate. However, Dennett coined the term “intentional system” for one “whose behaviour can be predicted by the method of attributing belief, desires and rational acumen” [108]. He distinguishes three [...] attitudes [...] in interacting with an entity, depending not on system complexity itself, but rather on the impact such complexity has upon the user (in the general sense of “interactant”): a) The mechanistic stance (the entity is regarded as a tool and its behaviour is predicted according to its structure; e.g., a hammer). b) The functional stance (the entity is regarded as a machine and its behaviour is predicted according to its utility; e.g., a text editor or anything else perceived as “black-box”). c) The intentional stance (the entity is regarded as a person and its behaviour is predicted according to the way the user estimates its intentions through empathy; e.g., a watchdog)” [96].

In short – and somehow oversimplified – intentional systems are the “anthropocentric subset” of the set of systems with autonomous behaviour. (And they should stay so.)

### 5.2.4. Bounded Rationality and Dennett Stances

In [65] the description was refined in the context of continuing education: “the concern is about what to teach *now*<sup>4</sup> within institutional education, to acquaint the students with their future tutors. Accent is on “now” since the scope and depth of understanding the role and make-up of agents will be guided by learner motivation and by teacher perspective. In this regard there are three stances, linked to the nature and the intensity of interaction, corresponding relatively to those described by D. Dennett [...]. Thus, when shifting towards [the Knowledge Society], the mechanistic stance will fade away gradually, the functional stance will be controlled by bounded rationality [...], while the intentional one will be inevitable. Indeed, paradigm shifts are urgent because of a matchless speed of change” [65].



**Figure 5.2.** The Dennett Stances [93], [96]

<sup>4</sup> My italics.

Obviously, the *tool is deterministic*, whereas the *person is* – at least, macroscopically – *nondeterministic*. As regards the functional stance, it shows the quintessential link between BR and “Just-in-Time”: “Extending Kowalski’s phrases from search to uncertainty, approximation, as a “don't care”-like uncertainty, can speed up remarkably data processing in key IT subdomains (e.g., image compressing) but is inherently unsuitable for “don't know”-like uncertainty, even in deterministic contexts (playing chess is a manifest example: certainty about the best move is given up to speed – better said, to inexorable time restrictions)” [64].

For the sake of communication effectiveness in continuing education two (chained) implications are cardinal for e-teaching:

- To be easily understood any nontrivial IT application must be empathized as an “intentional system” by both learner and teacher.

- The language should be “convenient” (in the meaning of Poincaré), namely anthropomorphic (besides Dennett, this is also defended convincingly by McCarthy, Shoham, Anderson; details and references are given in [9]).

### **5.3. STABILITY VS. CREATIVITY: BOUNDED RATIONALITY AS TWOFOLD FEEDBACK**

To become a truly *Lingua Franca*, any language – no matter how formalized – has to tackle its ambiguities. Here, this means to insert all polysemantic keywords into the Carnap-like glossary [14]. As shown in 1.2.2, the antonym pair “*positive/negative*” is inescapable and deserves a careful explanation of its various connotations in both *natural language* (5.3.1) as well as in *scientific context* (5.3.2). Next, based on clarified concepts, the twofold role of bounded rationality is investigated: *preserving stability* (5.3.3) and *boosting creativity* (5.3.4).

#### **5.3.1. Enthymems and “*Intentio Auctoris*”: Positive Connotations of “Negative”**

This excursion from the strict scope of the thesis is a consequence of the heutagogic experiment [65], [64], proved necessary because confusion is high even among successful IT high-school teachers.

The major ambiguity in the meanings of “positive” – among its over twenty connotations in [<http://www.thefreedictionary.com/positive>] – is between “Relating to or designating a quantity, number, angle, or direction opposite to another designated as negative” and “Measured or moving forward or in a direction of increase or progress”. The two connotations being widespread in natural language (at least in the modern languages that borrowed the neologism), enthymematic reasoning tends to become familiar and treacherous. Indeed, it seems that a memetic complex is emerging, based on a (subliminal?) equivalence between “positive” and “good, angelic, worthy, respectable” and so on. However, the memeplex becomes dangerous as regards the antonymic pair member, “negative”. Thus,



if the message sender and its receiver have in mind different lacking premises, the enthymeme – in its broader sense of “any argument some of whose premises are omitted as obvious” [<http://www.thefreedictionary.com/enthymeme>] – could generate huge differences between “*intentio auctoris*” and “*lectoris*” respectively. (For instance, a negative result of an important paraclinical analysis should be seen as “very positive”.)

Worse, the vicious meme contaminates negation itself as reasoning mechanism with unfortunate results – not only in applied everyday logic (above all in common decision making) – but in epistemology too.

Even worse, “[f]or Aristotle, who defined it in his Rhetoric, an enthymeme as a “rhetorical syllogism” which was based on probable opinions, thus distinguishing it from a scientific syllogism. It is aimed at persuasion while scientific syllogism is aimed at demonstration” [<http://www.thefreedictionary.com/enthymeme>]. “Klamer et al argue in their 2007 paper that Aristotle addressed enthymemes as maxims: “Aristotle noted that most arguments take the form of an ‘enthymeme’ (‘EN-thu-miem’), an incomplete or not-quite-air-tight syllogism. ‘Free trade is good’ or ‘Taxes reduce output’ are enthymemes, not-syllogistic arguments. The average French economist may find such arguments 45 percent true, whereas the average American economist may find them 80 percent true. Arguing an enthymeme is successful when the economist defends the 45 or 80 percent true as ‘true enough.’ Economics, [...] works in approximations.” [<http://en.wikipedia.org/wiki/Enthymeme>].

The quote above shows how context-dependent – hence hazardous – an enthymeme could be even when there is a common connotation: some premises were omitted not because they *are obvious*, but because they *should seem obvious* improving the look of a debatable argument [9].

Thus, “since, regarding ethics, not even conventional ICTs fulfil user expectations, it is *mandatory* to take into account ethical aspects when agents penetrate all innovative application domains. Moreover, it becomes *urgent* when their key purpose is to *interact* with humans [...], since they act consistently with their own *intentions* – regardless whether they are opponents (e.g., in e-commerce) or partners (e.g., in e-therapy). In fact, they try to *persuade*: from ancient rhetoric to modern advertising, “the power of persuasion introduces additional legal and ethical questions. [...] No simple list could empower agent designers to guide their agent development efforts ethically and legally” [133].

(Anyhow, applying enthymematic reasoning in captology is morally acceptable [9].)

### **5.3.2. From Barkhausen to Wiener: The Huge Positive Role of Negative Feedback**

In the case of obsolete approaches to engineering curricula (not only Romanian ones, [64]) communication quality is paramount. Moreover, such drawbacks are visible even in modern scientific approaches. The following example regarding feedback is revealing for educational undertakings from four (somehow overlapping, somehow embedded) stances [[http://en.wikipedia.org/wiki/{Feedback, Barkhausen\\_stability\\_criterion, Barkhausen\\_effect}](http://en.wikipedia.org/wiki/{Feedback, Barkhausen_stability_criterion, Barkhausen_effect})]:

- *limited horizon* (no reference whatsoever to GST);

- *sectorial scope* (no relationship between cybernetics, where it is fundamental and radio engineering or electronics where it comes from);
- *inadequate treatment* and poor explanation (no reference to a key macrofeature: system stability);
- *archaic content* (almost as a corollary, feedback is not regarded as both process and mechanism).

For instance useful sentences as: “Negative feedback helps to maintain stability in a system in spite of external changes. It is related to homeostasis. For example, in a population of foxes (predators) and rabbits (prey), an increase in the number of foxes will cause a reduction in the number of rabbits; the smaller rabbit population will sustain fewer foxes, and the fox population will fall back.” alternate with confusing ones as “In an electronic amplifier feeding back a negative copy of the output to the input will tend to cancel distortion, making the output a more accurate replica of the input signal” or even “Positive feedback amplifies possibilities of divergences (evolution, change of goals); it is the condition to change, evolution, growth; it gives the system the ability to access new points of equilibrium”. [...] Some assertions need badly to be improved (e.g., “Negative feedback, which tends to reduce the input signal that caused it, is also known as a self-correcting or balancing loop. [...] The terms negative and positive feedback can be used loosely or colloquially to describe or imply criticism and praise, respectively. This may lead to confusion with the more technically accurate terms positive and negative reinforcement, which refer to something that changes the likelihood of a future behaviour.” [<http://en.wikipedia.org/wiki/Feedback>].

From a CSITAO anthropocentric standpoint, filtered through the EU2020 objectives, and *in nuce*, feedback shows two hypostases: a) universal natural systemic *process* and b) versatile technologic *mechanism*:

- The *process* consists in taking a system’s output magnitude, processing it according to some architectural objectives, and feeding it back into the system together with the initial input.

- The *mechanism* consists in the rules allowing to carry out the feedback subsystem in order to achieve the system objectives.

In short, almost always in nature (e.g., homeostasis in living beings) and very often in technology (e.g., reducing noise and message distortion in communication systems) the target looked for is *preservation* (e.g., in living systems to prevent decay), or *stability* (e.g., in artificial systems to prevent deterioration). This basic kind of feedback is called – for obvious historical and physical reasons - *negative feedback*.

(From the above perspective a proposals is analysed to improve the Wikipedia article.)

### 5.3.3. Preserving Stability: Bounded Rationality as Negative Feedback

“Humans’ performances on most cognitive tasks are commonly regulated by an underlying latent variable (i.e., "general" intelligence) [...]. While "intelligence" in humans is easily recognized, a precise definition of this trait has proven elusive [...] For much of the history of animal studies of learning and memory, research has focused primarily on the processes

and mechanisms that regulate single domains of learning (e.g., spatial abilities or Pavlovian conditioning). While this tactic has been successful in delineating the neuroanatomical substrates of certain forms of learning and even learning domains [...], it has left unexplored those aspects of learning that are common across all domains. [...] "Higher cognitive functions" (such as reasoning, comprehension, and learning) are the hallmark of contemporary intelligence test batteries, and form common colloquial descriptions of "intelligence" [57]. For both psychologists and computer scientists, this text linking learning processes to cognitive functions is more relevant translated into "GST Lingua Franca" (e.g.: underlying latent variable = system variable; learning domain = subsystem). Other educational systems are teaching systems (human teacher or the bodiless agent acting as e-teacher) and learning systems (again, biologic beings or their virtual counterparts).

Quoting previous work, [64] asserts that "[t]he robot-portrait of a post-industrial engineer [...] is based on the shift from products to services, namely: [f]rom deterministic (closed, static, known) to nondeterministic (open, dynamic, partially unknown) environment. This holds for all educational systems: they are open, nondeterministic, and operate in dynamic and uncertain environments. Here the assertion acts as *Pr2*.

*Negative feedback* tends to keep parameter values, is corrective, conservative and promotes symmetry, stationariness, stability, reversibility. *Positive feedback* tends to increase parameter values, is evolutive, innovative and promotes chain reactions, ontogenesis, system increase (perhaps catastrophic, leading to system annihilation), instability, irreversibility [106].

For continuing education negative feedback is *sine qua non*, above all for the teaching process because it is *corrective*, and promotes *stationariness*, *stability*, and *reversibility*.

#### 5.3.4. Boosting Creativity: Bounded Rationality as Positive Feedback

In elegant mathematical clothing, [106] shows that while negative feedback is related to *control*, positive feedback is related to *organization*. The adjustments achieved through feedback behave like Maxwellian demons, i.e., they are anti-entropic – locally – creating organization islands consisting of agents (both natural and artificial), business organizations, and so on. The price? Their entropy-lowering effects are counterweighted by entropic degradation in the surrounding ocean. (The question mark is tackled in 9.3.)

The conceptual symmetry "negative-positive" is thus harshly broken: there is no duality, no complementarity (Yin-Yang reappears in 5.4.3). The outcome has set up a milestone for the EU2020 cluster, since a chain of implications emerges, building the framework for the seventh chapter as well as explaining the osmotic relationship with [26]:

- Any kind of education – always and everywhere – proved to be inertial, hence deeply conservative.
- Splitting the educational system into its key components – namely *teaching* and *learning* subsystems, respectively – it appears that, first of all, the teachers *exploit* their experience, avoiding risky innovations that could harm the learners. Hence teaching is conservative for both professional and moral reasons.

- On the contrary, the (motivated!) learners are rather predisposed to advance as soon as possible accepting the risk of *exploration* – above all when they perceive the counter-productive influence of teaching inertia. (Nowadays in Romania such a perception is very hard to escape from.)

- Applying the Occam's Razor heuristics, it is understandable that the link between BR and simplicity supports the prevalence of exploring BR as negative feedback – at least at this crossroad, in this thesis.

- It is too great a challenge to prove in the same context that the same mechanism – here BR – could generate antithetic types of feedback.

However, because of trends in continuing education, researching BR also as positive feedback becomes inexorable since teacher and learner are not anymore discernable educational subsystems. A possible way to shrink the gap is tried below. (Indeed, that is why synergy is looked for.)

In short, it can be argued that: a) long-term quasi-stability is preserved through BR acting as negative feedback (5.3.3); b) short interludes of creativity can be boosted through BR acting as positive feedback (5.3.4).

## **5.4. IN SEARCH OF SYNERGY FROM HUMANS TO ANTS. (BACK TO PHILOSOPHY?)**

After looking at synergy and analysing *where does it stems from* (5.4.1), its long prehistory and its fuzzy history *from Aristotle to Haken* are regarded through the thesis lenses (5.4.2), bringing to light the prospects offered. Then, reminding the fifth thesis objective, the way towards boosting the role of *semiotics* is suggested by heading at Eastern tradition (5.4.3). On this groundwork, the abstraction is reduced in 4.4.4, abridging from a CSITAO perspective the preliminary work necessary to apply BR in *modelling* in Chapters 6 and 8.

### **5.4.1. Synergy. Where Does it Stem From?**

This section is mainly based on [93], [97], [16], [7]. The ancient, best known, verified, versatile and affordable *universal lever* or – more wide-ranging – *resource amplifier* is *synergy*. Considered pragmatically, in its comprising Aristotelian (or Taoist) meaning, synergy was both obvious (nobody tried to give it a name) and enigmatic (nobody dared to explain it). Thus, the pre-terminological meaning of “synergy” due to Aristotle, still applicable today, is: *the whole is stronger than the sum of its parts*. (Much later, Hegel – and even later Marx – added to the synchronic dimension a diachronic one stating explicitly the link between “quantitative accumulation” and “qualitative jump”.) When eventually it got a name, the godfather was intuition: that “something” that was added to “the sum of the parts” is due to acting/working (“*ergon*”) together (“*syn*”), i.e., to *cooperate* (indeed, “*syn ergon*” is the same as “*co operar*”).

A speculative link to this thesis: besides being a fact, anonymous synergy suggested a totally new approach, starting the yet unfinished fight between *holism* and *reductionism*.

In the old and fuzzy meanings above, but from a modern scientific stance, synergy has three possible sources:

- *Homogeneous Amassing of Many Simple Entities*. Synergy is intrinsically linked to multiplicity. For instance, in stygmergy although ants behave rather as robots than as agents, the system they belong to is not a “multi-robot” system, but a “multi-agent” one. This wonder is due to the synergistic effect of their interaction: beyond the individual sub-systems (very simple entities in comparison with the system they belong to: ants, electrons, soldiers, believers, citizens, and so on), the system (colony, electric flow, army, religion, society, respectively) comes out. This kind of synergy (referred to as “classical synergy”) is intrinsically linked also to *parallelism*. Obviously, if it would be only “one part”, the “whole” could not be stronger than itself. However, multiplicity implies parallelism, not just because the „parts” creating the swarm coexist but because of their incessant – direct or indirect – *interaction* (imposed by the real-world dynamics). Where are communication, control, or algorithm? How can the “computational stance” resist anymore?

- *Heterogeneous Interacting of Few Complex Entities*. Dissimilar entities create “added value” rather by *complementarity* (e.g., in symbiosis) than by *sameness*. Physical entities (crocodile-bird) can be substituted by areas of expertise (surgeon-anesthetist), fields (education-psychology), sub-fields (robotics vs. agent orientation) or paradigms (symbolic, subsymbolic). In line with previous CSITAO experience in tackling synergistic effects – presented mainly in [93], [97], [16], [7] – this kind of synergy will be called also in this thesis “*inter-paradigmatic*” (the issue is commented upon in 5.4.4).

- *Trans-Disciplinarity*. The third source matches Prigogine’s idea mentioned in 2.4.3, about domain interfaces. It is a confirmed path for research (because of affordability, it becomes the only one). The prefix *trans* (instead of the usual *inter* or *multi*) highlights the trend towards osmotic-like confluences.

(Since not all connotations of those three kinds of synergy are suggested by the term “*emergent synthesis*” – more frequently used in modern CSIT contexts – in this thesis the term “*synergy*” is preferred.)

### 5.4.2. From Aristotle to Haken

Of course, the target of the EU2020 theses cluster involves mainly Aristotelian connotations for synergy. On the other hand, the PhD domain requires also a rigorous approach to modelling, no matter how human-oriented the domain could be. Thus, despite being anthropocentric *par excellence*, continuing education requires that any credible model – based or not on BR – should consider GST as “brainstorm repository”. Corollary: since Synergetics is a well-established science, Haken’s principles [131], [130] should be considered too. Fortunately, regarding synergetics as a meta-science, not all four principles are relevant for engineering modelling (each principle is followed by comments on its role in this thesis):

- “*The subsystems are slaved by the system*” is rather irrelevant because the educational system is heutagogic, hence the teaching and the learning subsystems are hard to

separate even conceptually. (This is quite common in real-world applications. For instance, an ant colony remains unexplained as *system*, albeit stigmergic control is very successful).

- “*Cooperating subsystems*” is rather pointless for continuing education being perceived as either pleonastic or nonsensical. (In fact, it is difficult to apply in classical synergy since cooperation between very simple entities is usually done via the environment. For instance, ants – natural or artificial alike – communicate only indirectly, through pheromones).

On the contrary, the next two principles have a huge applied research potential:

- *The “threshold” principle*. The background analogy is given by the von Neumann theorem regarding the complexity threshold for automata (separating involution from evolution) [Ct83]. No matter of causality relations, this principle is of unquestionable importance in both nature and real-world applications: a few ants are surely unable to run a colony and, as well, a few artificial ones are unable to solve research problems, no matter how long they try. In common language the threshold is called also “critical mass”.

- *The “self-organization” principle*. As conceptual crux of emergence, it expresses *autopoiesis*, the “order emerging from disorder”. Thus, it is the very foundation of heutagogic education: a self-organising system works without outside control, while the behaviours of its entities lead to an emergent coherent result. According to Heylighen [134], there are at least seven characteristics of self-organising systems. In continuing education context, four of them are relevant:

- global order emerges from local interactions (e.g., “εὔρηκα” or even Newton’s apple);
- distributed control (there is not a single general test);
- robustness and resilience (self-explaining);
- non-linearity and feedback (here the accuracy could be better: non-linearity refers probably to the positive feedback creating the avalanche effect while feedback refers probably to negative feedback).

Since by its very meaning self-organization is beyond outside control, it must be dealt with indirectly, applying the “threshold principle”. For instance, “*repetitio est mater studiorum*” implies that if complexity is high and time is short, the learning threshold (the moment when learner autopoiesis begins to emerge) is reached only after more repetitions (where autopoiesis emerges) in the desired direction. From an engineering stance, that means to attain the result more efficiently, i.e. with fewer resources.

### **5.4.3. Back to Lao Tzu: Synergy, Symbols, Semiotics**

“A good traveler has no fixed plans, and is not intent on arriving” [[http://www.brainyquote.com/quotes/authors/l/lao\\_tzu.html](http://www.brainyquote.com/quotes/authors/l/lao_tzu.html)].

At a first reading this quote (and the following ones even more) characterize this subsection as an essay, loosely linked to this thesis and to CSITAO research as a whole.

At a second reading the links become obvious since the quotes are directly related to this thesis’ key concepts, paradigms, approach and fabric.

At a third reading the essay appearance should vanish, the topic defending scientifically – albeit not “computationally” – the conceptual orientation: *Lao Tzu* is more

adequate for this thesis as both conceptual architectonic *milestone* (5.4.4) and experimental model *pillar* (6.3, 8.2, 8.3) than Aristotle.

All following quotes are from the source referred to above. The order is of decreasing abstraction (i.e., – somehow – from *approach*, to *architecture*, to *structure*):

- *Exploratory research*: “A scholar who cherishes the love of comfort is not fit to be deemed a scholar”. “To see things in the seed, that is genius”.

- *Bounded rationality as approach*: “All difficult things have their origin in that which is easy, and great things in that which is small”.

- *Bounded rationality as mechanism*: “Anticipate the difficult by managing the easy”.

- *Optimization could become counterproductive*: “Ambition has one heel nailed in well, though she stretches her fingers to touch the heavens.” “Fill your bowl to the brim and it will spill. Keep sharpening your knife and it will blunt”.

- *Heutagogy*: “He who conquers others is strong; He who conquers himself is mighty”.

- *The first two principles of Synergetics*: “Be the chief but never the lord”.

- *The fourth principle of Synergetics*: “An ant on the move does more than a dozing ox”. (Another subliminal message: pragmatic efficiency counts more than unused potential.)

- *Right-brain tactics*: “The power of intuitive understanding will protect you from harm”.

- *Uncertain environments*: “Those who have knowledge, don't predict. Those who predict, don't have knowledge”.

- *First and second order ignorance* [90]: “To know yet to think that one does not know is best; Not to know yet to think that one knows will lead to difficulty”.

- *Third order ignorance* [90]: “To realize that you do not understand is a virtue; not to realize that you do not understand is a defect”.

- *Captology is risky*: “Good words are not persuasive; persuasive words are not good”.

- *Successive prototyping*: “Do the difficult things while they are easy and do the great things while they are small. A journey of a thousand miles must begin with a single step”.

Though, why is Lao Tzu *better* than Aristotle? Because the essence – first of all the (mathematical) logic consequences – of his ideas are much more appropriate to (a Zadehian approach to) manage a service-based society. The problem is dealt with pragmatically in 5.4.4, based on the key disagreement about the possibility to achieve synergy otherwise than exploiting massive, fine-grain parallelism (first source of synergy, 5.4.1): “the Synergy of Complements is an inclusive principle: it does accept opposition, turning it to advantage. Unfortunately one cannot say this of the principle of the Exclusivity of Opposites” [139]. This is the essence of the second mechanism (6.3).

Indeed, again Lao Tzu: “The words of truth are always paradoxical”.

In short, to achieve *inexpensive* synergy, holistic approaches require *symbols* to express and exploit BR via the fertile and abundant ambiguity involved by *semiotics*.

#### **5.4.4. Back to Modelling: Synergy, Software, Sigmoids**

The consequences on CSIT – and first of all on modelling – are paramount: a) any model of an anthropocentric system should be based on symbols; b) a fortiori, any model of an educational system; c) more a fortiori, any model dedicated to continuing education; d)

even more a fortiori, any model aiming at synergistic effects; e) most a fortiori, any model involving BR. That involves a dramatic and multifaceted paradigmatic shift.

To ease the shift for all stakeholders involved – author and advisor included – three (very) long quotes from [21] set up the background for both the conceptual as well as the experimental model:

“Kuhn’s deflationary, antirealist sociological account of science demonstrated that scientific knowledge is not rational and objective, but dogmatic and close-minded as to its fundamental metaphysical assumptions, and is not cumulative or progressive, other than in an instrumental intraparadigm sense.”Mature science” – the “hard” physical and biological sciences – are not divergent but convergent with its own unconscious material realist worldview, opinions and expectations. Here, scientific research is not [...] so much evidentiary as dogmatic. Such normal science is always governed by a “paradigm”, a temporary general consensus among a community of practitioners about current methodology and foundational and fundamental principles. These paradigms then become ideologically entrenched and dogmatically defended. Eventually “anomalies” arise – problems or “puzzles” that cannot be resolved within the established paradigm. Such unsolved puzzles cause a “breakdown of the paradigm.” This precipitates a “scientific crisis” of confidence and an openness to a competing alternative paradigm” [21].

The consequences on software are paramount too: “Quine’s radical naturalistic epistemological holism undermines both common sense/naive Realism and Scientific Realism. [...]ur perception and cognition face the vast crucible of Reality Itself nakedly, without the epistemological staff of a foundational “first philosophy,” namely epistemological Realism. This radical holism regarding theory testability and verification [...] is also a holism of meaning. In place of the reductionism (meaningful statements are reducible to observation statements) of the Logical Positivists, Quine asserts that ultimately it is the whole of science, not mere propositions, that verify our theories and our paradigms. Scientific propositions or statements are a web of interconnected, interdependent, statements that ultimately constitute the whole of science, if not the whole of Reality Itself” [21].

Hence, no *processes* should be modelled via *objects*. (By the way, “learning object” sounds awfully obsolete; not even the “repository”-tag can make it palatable.)

“Is Aristotle’s syllogistic logic the last word? In this purely deductive logic, the Law of Contradiction and the Law of Excluded Middle are not apriori true assumptions, but are logically deduced from the definition of contradictories as stated in the Law of Contradiction itself. But in the Eastern logical canon the truth of a statement is not logically equivalent to the falsity of its contradictory [...] Is the human mind then, entirely bound by the logical syntax of this binary purely deductive, merely two valued truth-functional logic? Are we forever yoked to a bivalent, bipolar view of reality that logically excludes the holism of both A and not A? This dichotomous, black and white mode of thinking, this pernicious and unconscious intersubjective mythos of dualism has infected the history of ideas in the West – religion, science and culture – and we’re not even aware of it!” [21].

Hence, modelling should be based on algorithmic thinking as less as possible. At least, if old paradigms are yet too powerful – or if nonalgorithmic mechanisms are too hard to



access – binary forks (namely “if-then-else” statements) should be replaced by more conceptually palatable multiple forks expressing CWA (*closed?-world* assumption). The simplest such fork is a “switch” statement. Therefore service-oriented applications should be implemented based on such forks (6.1, 6.3.2).

As regards the *sigmoid*, CSITAO experience in stigmergy-related research [97], [16] shows that remarkable engineering results can be obtained when the mathematical foundation of modelling is focused on the sigmoid function (and on the Heaviside function as its limit) instead of classical optimization methods.

In short, to achieve synergy, modelling requires innovative (i.e., *nondeterministic, non-categorical, agent-oriented*) software no matter the (quintessential?) role of sigmoid.

## SIXTH CHAPTER

### Non-Algorithmic Mechanisms for Word-Based Modelling

*Bounded rationality is best perceived  
when facing unbounded irrationality*

Despite its rank, this chapter is chronologically the last, written after failing to suggest a believable interpretation of the relationship between post-industrial decision making and BR. Thus, thoroughly reassessing the results so far, it seemed necessary to restate the start vector (2.2.2, 2.2.3, 2.4.1) focusing now on *post-industrial modelling* outlined from an explicitly decision oriented stance (6.1). Likewise, two innovative mechanisms – albeit in simple and old programming clothes, according to the approach (2.4) – were separated from the experimental model they belong to and reshaped as *non-algorithmic decision support* instruments (6.2, 6.3).

#### 6.1. CONCEPTUAL OUTLINE OF POST-INDUSTRIAL MODELLING

To avoid any ambiguity, the *requirements for DSS* (6.1.1) and *for AO* respectively (6.1.2) are grouped separately despite their architectonic and structural interference. *Resource limitations* (mandatory for modelling in engineering) are examined (6.1.3).

##### 6.1.1. Requirements for Post-Industrial Decision Support Systems

For the sake of transdisciplinarity it seems wise to keep for the time being the term “*decision making*” for humans and “*autonomous behaviour*” for all entities it “stems from: living beings, automata, and software” [10] (5.2.2, Figure 5.1).

According to the start vector (2.2.2) interpreted in the light of the connotations assumed (5.2.2 and above), this thesis asserts:

- All achievements of decision making (including all DSS developed according to [122], [46], [120], [123], [124], [119], [103], [104]) are considered as both necessary and valid in the post-industrial society.

- The challenges of continuing education appear practically also in most (non-trivial) decision-making. However, the paradigm changes implied request reasserting them explicitly here as *premises for post-industrial decision making (PrPidsDM)* despite redundancy with the start vector (2.2.2).

- *PrPidsDM1*. In a post-industrial (service-based) society chaoplexity is pervasive (not just *educational*, but *situational* in any dynamic and uncertain environment)

- *PrPidsDM2*. Any decision to be effective must be made “Just-in-Time”.

- *PrPidsDM3*. Decision making *is* autonomous behaviour *par excellence*.

- *PrPidsDM4*. Since both *nature* (i.e., situations needing decisions) and *humans* (i.e., decision makers) are *analog* and *nondeterministic*, it is increasingly awkward to rely on *numeric* and *algorithmic* decision support.

- *PrPidsDM5*. Any model of anthropocentric decision support should be based on symbols *accessible through the interface*.

- *PrPidsDM6*. Conventional (optimization-based) methods become unsuitable for decision support simply because (quasi-)timeless services are out of the question in real-world settings.

In other words: a) there are real-world situations where conventional-DSS-based decision making is *ineffective* or even *unacceptable* (when late decisions are harmful, *Pr1*, *Pr2*, *Pr4*, *Wa2*, *Wa6*); b) decision making in line with “BR+JIT” could be vital when switching from *automatic* to *manual* control is not suitably managed in risky situations (6.3.1, 7.2.3, 7.2.4).

As regards the prevalent mentality mentioned in 4.3.1 about therapeutic decision-making as exclusively human attribute, it is now accepted (and even common practice) that *low-level decisions* – including most of those made during intensive therapy – can be “delegated to other entities able to manifest autonomous behaviour” (the speech marks reflect the effort to avoid pointless arguments).

On the contrary, *high-level decisions* (mainly under time and/or risk pressure) should remain – at least for the time being – a last human privilege in withstanding alienation through technology (no tool or machine should be allowed to take initiative in vital matters).

Nevertheless, there is a major hindrance, due to a yet prevalent mentality: since (high-level) decision-making is an exclusively *human* attribute, non-algorithmic *software* is – if not nonsensical – applicable at most to toy problems.

A key role of this chapter is to challenge convincingly this prejudice.

### 6.1.2. Requirements for Agent-Oriented Mechanisms

Below are listed only the main requirements that are effectively mirrored in mechanism architecture (6.2, 6.3) because: a) it is useless to repeat requirements established over twenty years ago; b) in a post-industrial society regarding the agent as service-provider (based on the very agent metaphor) is more relevant than looking for its weak or strong features (reflected in standards or just in advanced IT practice). (In parentheses examples are referred to.)

- The paradigm shift from *using* (conventional) *software* to *interacting with* (bodiless interface) *agents* is vital. (6.2.1, 6.2.2, 6.3.1, 8.2.1, 8.2.4.)

- Corollary1: Interfaces should be anthropocentric. (Idem. Details in 6.2.1.)

- Corollary2: In line with *Wa3* all input is natural, i.e., analog. (Idem. Details in 6.2.1.)

- Corollary3: In line with the paradigm of “computing as interaction” in “technologically unmanageable” environments (expanding, changing, unsure, and fuzzy) intentionality is not restricted to humans. Indeed, agents interact with humans and with their non-human environment consistent with their own intentions” [9]. (6.2.1, 6.3.3, 8.1.3, 8.2.4.)

- Corollary4: In line with *Wa4* cognition is regarded as holistic. Decision making must be based on: a) holistic approaches, requiring right-brain – intrinsically non-algorithmic – techniques; b) accepting uncertainty. (6.2.3, 6.3.2, 6.3.3, 8.3.3.)

The last corollary marks somehow the shift from the fourth to the fifth objective as well as from *requirements* to exploratory (innovative) *features*. There are four echelons:

- Replacing numbers by words as much as possible. (Integrating the word-based bar devised in 6.2 into the experimental model for simple but urgent decisions designed in 8.2.)

- Lessening the weight of *categorical* – mainly dichotomous – concepts. (6.2.2, 6.3.2, 6.3.3, 8.4.2)

- Lessening *graphocentrism* through *nontextual* interface components (8.2.4, 8.3.3, 8.4.2)

- Lessening *logocentrism* through *nonverbal* interface components (8.3.3, 8.4.2).

In short the mechanisms should work incorporated in an agent designed as service-providing software entity, based on multimodal interfaces and aiming at decision making with incomplete information.

### 6.1.3. Resource Limitations

The order is from abstract to concrete (the effect upon this thesis was rather in inverse order to that of the account; in parentheses are examples):

- *Depth of transdisciplinarity*. This limitation was threefold: a) no cooperation within “Prigogine niches” was set up ([62] or [61] had no feedback whatsoever); b) in some relevant disciplines the reigning paradigms are scarcely reevaluated (cognitive psychology); c) main application fields have no suitable theoretical framework for BR or JIT for the post-industrial society (service-oriented theory of value).

- *Conceptual framework*. No matter the disciplines they stem from, key concepts like *nondeterminism*, *uncertainty*, *cognition*, *chaoplexity* (including the old components the new concept is derived from), *stimulus*, *organization*, and –above all – *time* have no (scientific) definition or have a variety of (divergent) connotations (*organization* as “social arrangement” versus *organization* as “time derivative of *order*”).

- *CSITAO terminology*. There are two kinds of conceptual hurdles: a) stemming from the way general concepts are mirrored in this thesis (“*non-algorithmic*” reflects “*uncertain*” as epistemic facet of “*nondeterministic*”); b) stemming from incompatible meanings concocted in CSIT itself (the Turing-machine-based definition of *algorithm* is inapplicable neither to “genetic *algorithms*” nor to so-called *programs* based on script languages). If the first type of difficulty was overcome – at least partially – by [14] the second one is an overwhelming endeavour for any PhD thesis.

- *Affordability*. Besides the whole range of logistic restrictions occurring in a medium-sized Romanian university, lacking a suitable API was most likely the most influential. Thus, it requires to be dealt with separately below.

#### 6.1.4. Simulating Bodiless Agents

As explained in 2.3.2, 2.3.4, 2.4.2, the interface agent is *sine qua non*. Hence, if it cannot be implemented it must be simulated. However, if it is simulated by the decisional free will of its owner in an experimental model of a CSIT thesis, engineering credibility requires to prove indisputably that: a) the model *architecture requires it* to illustrate its innovative features; b) the *structure* involved *is unaffordable*; c) *validation is still unaffected*.

- *Architecture*. The nondeterministic behaviour of the complex interface agent is essential to achieve the first three thesis objectives (mainly 2.2, 2.3, 2.4, 4.3, 5.4).

- *Structure*. An *affordable* IDE means (according to *Pr5*): a) widespread (CSITAO intention); b) compatible with EU2020 modelling ([26] rationale); c) available (thesis prerequisite). *Available* means: accessible (here and now) and either offering Ada-like language primitives for advanced concurrent programming or allowing API-based multithreading. Since event-driven multithreading is not supported by any common API – including that of Windows 32 (mainly because of the drastic architectonic limitations imposed by object-orientation – nondeterministic behaviour must be emulated via one of the other two manners allowing *asynchronous interaction* through the interface (other than the usual keyboard or mouse interrupts): a) genuine exception handling (i.e., allowing dynamic propagation); b) script or mark-up languages (or at least other interpreted, not compiled software entities). For reasons detailed in 6.2.1 the second way was chosen for the first implemented mechanisms. (However, as shown in 7.2.3, for the experimental model needed by [26] at least the development of an Ada-like exception handler is unavoidable.)

Thus the only major service-oriented innovation currently implemented is the well-known – but rarely used – “*return-1*” (6.3.3, 7.2.3, 8.1.3, 8.1.4, 8.4.2, 8.4.3.1).

- *Validation*. Service-oriented validation in line with *Pr1*, *Pr2*, *Pr5*, and *Wa2* is performed *in embryo* for both mechanisms and *in ovo* for the real-world toy problem (8.1.2).

## 6.2. MULTIFUNCTIONAL WORD-BASED BAR FOR NON-ALGORITHMIC INPUT

The description is self-contained because the mechanism is: a) *autonomous* (designed to be applied beyond this thesis – first of all in [26]); b) *novel* (redundancy with previous research is minimal); c) *integrated* in the experimental model (thus, chapters 7 and 8 can be better focused on modelling and on model implementation). After summarising the *rationale for word-based interfaces* (6.2.1) and abridging *previous work* showing that *non-algorithmic software* does not start from scratch (6.2.2), the *generic mechanism architecture* is explained for the case of a (*pseudo*)*linear decision-input bar* (6.2.3). To be suitable for continuing education, the *psychophysical (logarithmical) bar* is prepared for (6.2.4).

### 6.2.1. Rationale for Word-Based Interfaces

The rationale does not refer explicitly to decision input because – besides being purposely *autonomous* and *aiming at decision making* – the mechanism (based on the *analog input bar* presented in 6.2.2) proved to be *general* and *ergonomic* (6.2.3) as well as very *easy to implement* (6.2.4). Thus, for the sake of simplicity the reasons will be presented together gathered them from above – mainly from the requirements for post-industrial decision support systems (6.1.1) and for agent-oriented mechanisms, respectively (6.1.2).

However, the first reasons stem from the start vector (2.2.2): *Pr4*, *Pr5*, *Wa2*, and above all *Wa3* asserting that *analog* input is *natural* and *general*. The reasons have been specialized for DSS (6.1.1): *PrPidsDM4* confronts both *numeric* input and *algorithmic* support (situations needing decisions and humans making them are *analog* and *nondeterministic*). *PrPidsDM5* asserts the *need of symbolic interfaces* (because of anthropocentrism) and re-asserts the *role of any interface* (the symbols must be accessible *through* it).

Focusing on *post-industrial modelling* (from a definitely *decision oriented* stance) a cardinal reason emerges: interfaces must be *user friendly* and *ergonomic* (in boundedly rational terms “*simple*”) because: a) humans must make decisions “Just-in-Time” and mostly in the absence of complete information; b) a common denominator is welcomed since there are two kinds of decisions, intentionality is not restricted to humans (6.1.2), and swift swapping between “manual” and “automatic” mode should be encouraged.

In short, if proper human decision making is challenging and hard to explain because of BR, this very BR should at least help to keep it as easy as possible.

### 6.2.2. Non-algorithmic Software. Previous Work

Aristotelian, bivalent logic – conventional software is based upon – resisted theoretical blows administered by various types of logic (e.g., logics for AI, fuzzy logic). Thus, decision support – and software as a whole – is still overwhelmingly algorithmic. (A Google search from 2011-10-07, revealed about 4,540,000,000 results for “software” and only about 300 results for “non-algorithmic software”!). In spite of this, previous CSITAO work shows that:

“DSS weaknesses stem from inappropriate conceptualising, based on rigid, algorithmic (i.e., deterministic, almost sequential, “computational”, and atemporal processing), meant for decision making as “step by step solving of arising sub-problems”, not for decision making as “continuous process of dealing with unexpected, potentially risky, fast changing situations requesting immediate - albeit not optimal - response” [13], [17].

[17] proposes a “general software mechanism developed primarily for decision making in dynamic and uncertain environments (typical application: managing overbooking). DOMINO (Decision-Oriented Mechanism for “/F” as Non-deterministic Operator)” [17].

In combining non-algorithmic software with word-based computing, the most daring linguistic variable suggested was *ethics*, since “the behaviour of software agents must show a wise blend of ethical intransigence and pragmatic effectiveness. Therefore, the different elements of ethics required in the design process need to correspond to categories of ethics as system, expressing various degrees of rigor. At one extremity, one has the strict deontological form of ethics [...], at the other end one has Epicurean act-based

pragmatism [...] somewhere in between one can place rule-based utilitarianism” [9]. (This “ethical potentiometer” was never implemented since the PhD thesis intended to devise “user-driven ethical behaviour of self-aware agents” was abandoned.)

### 6.2.3. Generic Architecture of a (Pseudo)Linear Decision-Input Bar

Architectonic targets: a) Advancing decision support to tackle post-industrial situational chaoplexity based on bounded rationality (as main cognitive mechanism for decision making) together with “Just-in-Time” (as post-modern variant of “real time”). b) Conceiving a multifunctional input bar for decisional choices based on fuzziness, computing with words, cognitive psychology, non-algorithmic software and semantic validation. c) Illustrating the above by the design and implementation of a “Decision-Input Bar” instance applicable in common and urgent situations. The last target is postponed for and attained in 8.2.

Starting from the targets, the mechanism title is easy to explain:

- *Non-algorithmic input*. As shown in 6.2.2, it is in fact the IT mirroring of the paradigmatic shift towards recognizing the *non-algorithmic nature* of high-level *information processing* by humans. The – still unusual – concept is extended here from continuing education to decision making as a whole.

- *Input Bar*. The decisional choices are entered into the system expressed as pixel segments on (scrollbar-like) bars. The segment length represents the choice variable value.

- *Word-Based*. Boundedly rational decision making rejects both extremes of choice granularity: *two* choices (in line with the Aristotelian “excluded middle”) or an *infinity* of choices (in line with the mathematical distortion of Zadeh’s sound principles of fuzziness and fuzzy thinking [64]). (Similar problems are debated currently in the BISC community).

In short, “computing with words” should mean for decision making – above all when chaoplexity impairs “Just-in-Time” decisions – *Rationale 3* according to *Wa5* (in vital decisions, even *Rationale 4*, according to *Wa6*). Thus, “*Word-based*” means: “as many words as necessary, as less computing as possible”.

- *Multifunctional*. To keep the interface simple (cognitive ergonomics is paramount for “Just-in-Time” decisions) structural differences should be kept minimal. Thus, an input bar for an action depending on a perception governed by a psycho-physiologic logarithmic law can look the same (indeed, a linear scrollbar and a volume potentiometer are very similar).

- *Successive prototyping*. Corollary of the above.

### 6.2.4. Preparing for Psychophysical (Logarithmic?) Dependence

“The (invariant) ratio between stimuli that reach the possibility of being distinguished – called supraliminal stimuli - was measured by Weber in 1834. Later, Fechner (1860) formally expressed th[e] invariance in the Weber’s fraction as the *first psychophysical law* [...] Possibly, there is a dependency between the ability of species discriminate stimuli of a particular sensory modality and the constancy in the expansion or contraction process of the sensation to the physical reality. According to Fechner, the dependency between perception and stimulus is logarithmic. This relationship is known as *the second*

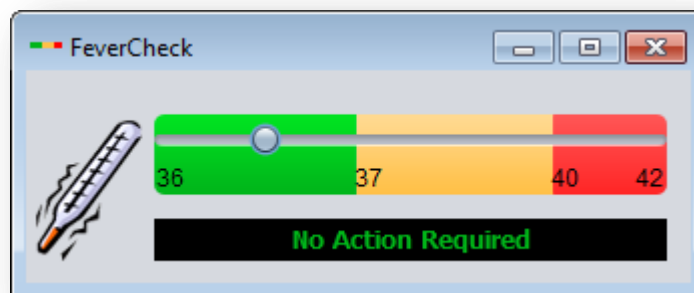
*psychophysical law* or the *Weber-Fechner law*:  $\tau(t) = a \ln(1 + bt)$  [...] where  $\tau$  is the subjective time, and  $a$  and  $b$  are psychophysical parameters” [32].

For a self-contained and structure-oriented section the technical – albeit trans-disciplinary – information above suffices. (Applying self-recurrence to this “service-oriented thesis” the huge architectonic significance of logarithmic dependence for continuing education is questioned – in both meanings of the word – in the user-oriented section 7.4.4.). Here only examples of implementation-related aspects of successive prototyping are dealt with:

- *Function type*. There are two sorts of perception level: *biological* and *cognitive*. Hence, “logarithmic dependence” is too ambiguous for designing an input bar for an action depending on a perception governed by a psycho-physiologic logarithmic law. What is its analytical expression (*exponential*, or *sygmoidal*, or purely *logarithmic*)?

- *Graphic look*. Even if (types) of dependence are similar, some patterns got memetic value (and stability too). For instance, *certainty factors* can be input easily into a bar [92] but for a “*cos φ meter*” a circular form is more likely.

- *Granularity*. As shown in 6.2.3.1 it is quintessential for “Zadeh-word-oriented” input: The “ethical potentiometer” ([9], 6.2.2) had five discrete positions, the “thermogram” segments in Figure 6.1 differ not only in values, but also in *granularity* reflected in *scale*.



**Figure 6.1.** Linear fragment of a (pseudo)linear input bar.

### 6.3. NON-ALGORITHMIC SERVICE-ORIENTED DECISION-MAKING FRAMEWORK

Essentially different from the word-based bar above, the mechanism presented here is rather a set of cardinal design principles for post-industrial CSITAO applications. However, a sufficient yet paradoxical reason to label it as a post-industrial software mechanism, is the *rara avis* instruction: “*return -1*” (6.3.1). The next guideline for service-oriented software refers to *tackling uncertainty* caused by future contingent *in DSS* (6.3.2). Other basic development practices *challenge Chrysippean bivalent logic*, but within the frame of conventional algorithmic imperative programming languages (6.3.3). The apex is to realise



the need of and to offer the tools for *switching* control from humans to *software* and back (6.3.4).

### 6.3.1. “*return -1*”, a *Rara Avis* Counterpart of the Familiar “*return 0*”

To explain the (both innovative and essential) role of the “service-oriented semantics” given to a very rarely used variant of “return”, a minimal analysis of (bad) programming practices is useful. There are three problems with a “return-type”<sup>5</sup> instruction, no matter the programming paradigm used: a) who returns? b) *what* does it return? c) it returns to *whom*?

a) If the entity translates a usual algorithm from “START” to “STOP”, namely if it is a (main) program receiving control from the OS or a subprogram having no data type (and value) attached to its name (e.g., a “procedure”), then “return” means “STOP”. Otherwise – namely when the entity is a “function” – “return” embodies the function *value* (e.g.,  $y = f(x)$ ).

b) Confusion arises in languages where any procedure (main program included) is considered as a particular case of function - and not *vice versa* as both older programming languages and common sense require. As a result, any code entity must return “something”, no matter how useless or – sometimes even – meaningless it might look. (However, since it exists syntactically, it can be put to work, having assigned some meaningful role.)

c) That should be straightforward: any *called* entity returns values to its *caller*, when it returns control. Thus, why should an application program care about return values, since they are useful – at most – to the OS (its only possible caller)? That is why most compilers don’t care about the value – some compilers even ignore the instruction altogether.

On the other hand, in service-oriented applications software entities must have a non-algorithmic temporal dimension, i.e., they should be seen as *processes* or *threads* that provide a service to their caller. Obviously, any service provider – living or software entity alike – *must* keep its client informed about the service evolution. A minimal information should be about *success* (normally expressed by “*return 0*”) or *failure* (unfortunately mostly ignored but, if signalled, usually expressed by “*return -1*”). There are three possible kinds of caller: a) the OS (practically the only caller treating the API functions as service providers, i.e., using as many return values as required by service robustness); b) an *application software* entity (the main program or another subprogram); c) the *end user* through the interface (either directly or via an interface agent).

Of course, a second value is mandatory because any “Yes” is meaningless without the possibility to say “No”. (The values “0” and “-1” are borrowed from the API functions of early real-time OS, where, for historical reasons, errors had negative integer codes.)

It seems strange that avoiding “*return -1*”, even elementary bivalence was abandoned for a delusive “algorithmic service with Turing-like unique termination” – unimaginable nowadays in the real world.

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<sup>5</sup> “*return-type*” is meant to emphasise that the analyse is language independent. However, it is presupposed that the OS has at least a *Windows API* and it is tacitly accepted that the programming language used for a mechanism should be a popular one, namely *C++* or *Java*. Similarly, “*otherwise*” should be regarded as pseudocode concept – namely including all programming language variants, first of all “*default*”.

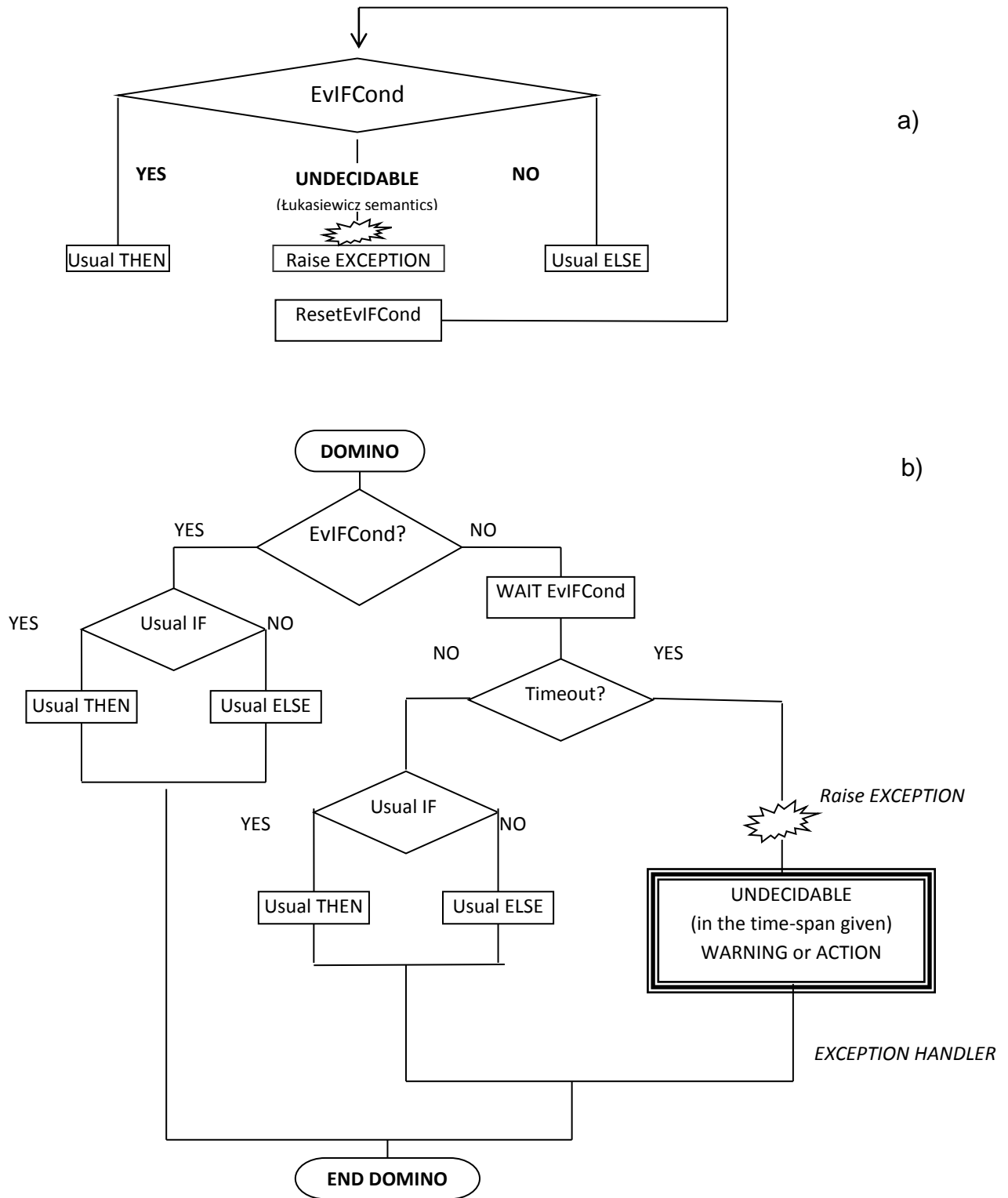
In short, the innovation based on BR is: a vital architectonic feature (“service failed”) can be expressed by a simple and until now unused instruction (“*return -1*”).

### 6.3.2. Post-Industrial Decision Support, Incomplete Information, and Procrastination

This mechanism component is a mechanism *per se* [17], stemming from previous LBUS research (2.1.1). It is summarised here after [100], [17], [64] only because: a) it is a key constituent of the non-algorithmic decision-making framework; b) it is the first time it is applied to an experimental model (although not implemented in the first prototype).

“The main weaknesses of current IT systems are investigated in [13] [...]. Since DSS weaknesses are very similar, they are stated here adapted and abridged from [13]: they stem from inappropriate conceptualising, based on rigid, algorithmic (i.e., deterministic, almost sequential, “computational”, and atemporal processing), meant for decision making as “step by step solving of arising sub-problems”, not for decision making as “continuous process of dealing with unexpected, potentially risky, fast changing situations requesting immediate albeit not optimal response”. Sectorial aspects are: *Poorly reflected* (or absent) temporal dimension. Limited parallelism (if any), [...] no exception propagation; no dynamic priorities; [...] *Misunderstood uncertainty*. Even if the fact that accurate numeric data are hard to get is accepted, the emphasis is on approximated, predicted, evaluated by rule of thumb, or even on intrinsically fuzzy data, rather than on missing ones (lacking sensor information, delayed previous decisions, server crash etc.). *Distorted prediction*. Bayesian inferences are considered unsuitable to decision-making because “Even if decision-makers could get all answers in due time, would they believe them strongly enough to make critical decisions only on their basis? Humans are not “probabilistic beings” and are very prone to any sort of “gambler’s fallacy” [16]” [17].

“DOMINO (*Decision-Oriented Mechanism for “IF” as Non-deterministic Operator*) was “developed primarily for decision making in dynamic and uncertain environments (a typical example for potential application area comes from the overbooking policy of carrier companies) [17]. “It acts as an “IF” with enhanced semantics: “YES”, “NO” or “UNDECIDABLE in the time span given” (it renders control to an exception handler). Despite its trivalent logic semantics (the third value is a blend of a Łukasiewicz “i” interpreted as “unknowable” or “problematical” and a Kleene “u” interpreted as “temporary lack of knowledge”), it respects the rigours of structural programming and the syntax of bivalent logic, being programmed in plain C++” [17], [64] (Figure 6.4).



**Figure 6.4.** DOMINO (adapted from [17]) a) *Architecture*: trivalent logic semantics  
 b) *Structure*: bivalent logic implementation (based on *Windows API*)

### 6.3.3. Other Non-Chrysippean Practices in Service-Oriented Software

After explaining the reference to *Chrysippus* and *why should it be OTHERWISE?* (6.3.3.1), it is shown how “OTHERWISE” is able to: get rid of “*tertium non datur*” (6.3.3.2) and *reconcile abduction with algorithmic software* (6.3.3.3).

#### 6.3.3.1. Aristotle or Chrysippus? Why Should It Be OTHERWISE?

Chrysippus is referred to here as “pillar of bivalence” because: a) Aristotle as “father of philosophy” is a better counterbalance to Lao Tzu, whereas Chrysippus as “father of logic” is the originator of formal languages (including a strange but unquestionable definition of “IF ... THEN”). b) In Stoic logic “disjunction is exclusive and non-truth-functional” [22] c) Despite its tough deterministic stance, he was a forerunner of the trivalent “IF” proposed above: “Like Philo and Diodorus, Chrysippus distinguished four modalities and considered them as modal values of propositions rather than modal operators; they satisfy the same standard requirements of modal logic. [...] Chrysippus' modal notions differ from Diodorus' in that they allow for future contingents and from Philo's in that they go beyond mere conceptual possibility” [22].

Thus, “non-Chrysippean practices” refer to allowing flexible and varied service providing within the structural frame of popular programming languages. Both are based on extending the use of “OTHERWISE” in conditional statements.

#### 6.3.3.2. Replacing “IF” by “SWITCH” with “OTHERWISE”

As shown in Figure 8.4, it means liberating the application design from the mental pressure of “*tertium non datur*”. The usual reference to the “excluded middle” is here avoided since: a) there are *multiple* architectonic *alternatives*, nothing about some *intermediate value*; b) mainly during the “Service-Outlining Dialog”, the “otherwise” option is more than just another possibility. Indeed, it offers the advantages of an “emergency exit”: security, robustness, “Just-in-Time” improvise, and so on.

Though, the shift from Aristotle to Lao Tzu in DSS, looked for in this thesis will become evident in 6.3.4.

#### 6.3.3.3. Reconciling Abduction-Based Reasoning with Algorithmic Software in DSS

Abduction-based reasoning is relevant here – and for this thesis as a whole – because: a) as based on “the best explanation” it is closely related to BR; b) moreover, it is a type of nonmonotonic reasoning appropriate for decision making in dynamic environments with incomplete information; c) it can be reconciled with CWA (hence with conventional software) via “OTHERWISE” as shown in Figure 8.4; d) an essential category of services, namely *diagnosis*, relies heavily on it. Indeed:

“Abduction or [...] Inference to the Best Explanation is a type of inference that assigns special status to explanatory considerations. [...] it violates monotonicity, meaning that it may be possible to infer abductively certain conclusions from a subset of a set S of premises which cannot be inferred abductively from S as a whole. [...] Even if it is true that we routinely rely on abductive reasoning, it may still be asked whether this practice is rational. For instance, experimental studies have shown that when people are able to think of an

explanation for some possible event, they tend to overestimate the likelihood that this event will actually occur. [...] Finally, a possibility that has so far not been considered in the literature is that abduction and Bayesianism do not so much work in tandem [...] as operate in different modes of reasoning; the Bayesian and the explanationist are characters that feature in different plays [...]. In fact, it is an open question whether there is any straightforward connection between the two, or even whether there is a connection at all” [33].

#### 6.3.4. Detaching “Manual” from “Automatic” Control in Service-Oriented Software

Acknowledgments: a) this section was attached to this chapter after the thesis has been assessed at different echelons; b) the arrows in Figure 5.1 too; c) neither the section, nor the arrows are necessary because the very problem of “detaching” the two processes is incongruous; d) on the contrary the problem of “switching” is ubiquitous – hence trivial (any tele- or interphone responder shows it daily); e) moreover, switching is so straightforward in almost<sup>6</sup> all real-world situation that it is unnoticed; f) “detaching” was meant here as “mentally” not “technically”; g) worse, “detaching” is not part of the *solution*, but of the very *problem*: *paradigm shifting* (not *switching*) needs a preliminary step: admitting that other paradigm *may* (or *could*) exist and that any research should be assessed according to *its* start vector; h) claiming to be *conservative* is a sign of great *sincerity* but is of little *help*.

Immediate causes for “attaching” 6.3.4 to a thesis it does not belong to were some important criticisms like: a) it is dangerous to use “chaoplexity” without having defined “chaos”; b) the experimental model does not illustrate the thesis title because “pattern recognition” is regarded as involving artificial neural networks or similar IT techniques.

Since it is useless to defend *stances* – above all when they are paradigmatic – the rest of 6.3.4 is organized (sic!) as a (mini)set of open (sometimes even tacit) questions (but without question marks to avoid rhetoric or polemic inflections).

- Haken asserted the threshold principle based on *noticing* (observing, verifying, even establishing), not *explaining* (even less *defining*) the difference between the states (order vs. disorder) of electrons in metals manifesting superconductivity.

- Complexity was studied *before* and *without* defining “chaotic”, “self-organization”– or even some “more tangible” antinomies: “simplicity”, “cosmotic”, “(exogenic) organization”.

- There are real-world situations where it is vital to accept that: a) there are two kinds of decisions; b) intentionality is not restricted to humans; c) switching from “manual” to “automatic” mode should be encouraged and swift.

- Metaphors apart, “pattern recognition” could be legitimate for humans too (a “pattern” is – at least macroscopically – holistic, whereas “recognition” may be linked rather to “cognition” than to “machine learning” (there are yet some differences between “learning” and “clustering”).

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<sup>6</sup> “Almost” means that there are some unfortunate exceptions like Apollo 13 or Fukushima

- It may be legitimate to put the *ends* (“pattern recognition”) above the (sometimes use-  
less) *means* (“(un)supervised learning”).

As a result, Figure 5.1 can be commented upon in 8.3.3 and formulated as open  
question in 9.3, based on three “credal beliefs”:

- The prevalent paradigm is valid for “automatic control”. Decisions are focused on pre-  
cision and are made by robots. They are mathematics-based, algorithmic, and carried out  
mainly through *object-oriented* IT. Time is either noninteresting (the algorithm stops when  
the problem is solved) or circular (“return” means not “stop”, it means restarting an endless  
loop).

- The new paradigm is valid for “manual control”. Decisions are focused on bounded ra-  
tionality and are made by humans. They are semiotics-based, non-algorithmic, and carried  
out mainly through *process-oriented* IT. Time is “Caesium Time” only in simple situations,  
it must be similar to “Carbon Time” [12], [8] because services (decision support included)  
are for humans (“return” must be semantically enriched, since “return -1” is mandatory for  
warning the user that the service failed).

- In the industrial (*product-oriented*) era, the prevalent paradigm was *sufficient*; in the  
post-industrial (*service-oriented*) era, both paradigms are *necessary*.

In short: the input bar is applicable no matter the paradigm involved, while the guiding  
principles are aimed to become a *PIPE* (*Post-Industrial Programming Entity*<sup>7</sup>), as substan-  
tiated in 8.3 and implemented in 8.4. Whether it would be an *ADVANCED* one is assessed  
in 9.2.2 and validated (or not) through future work outlined in 9.3.1.

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<sup>7</sup>*Programming Entity* is a provisional label until there is enough evidence to give up the obsolete “programming” and  
call the “entity” by its name: *protoagent* (reasons are given in 8.3.4).

## SEVENTH CHAPTER

### Boundedly Rational Experimental model(s) for EU2020 Targets

*Man cannot remake himself without suffering,  
for he is both the marble and the sculptor.*

ALEXIS CARREL

After presenting the key problem of continuing education, namely the *postmodern "educational chaoplexity"* (7.1), because of speeding up this thesis, the second subchapter is reduced to the level allowed by cooperation results achieved so far [26], presenting *e-teaching as boundedly rational (sub)system*. Focusing on the temporal hiatus intrinsic to continuing education the solution proposed is to *extrapolate* a lasting topic (*The Golden Ratio*, 7.3) and a lasting behaviour (*The Damascus Blade*, 7.4).

#### 7.1. POST-MODERN EDUCATIONAL CHAOPLEXITY. BOUNDEDLY RATIONAL MODEL

Before launching the concept of "EDucational CHAoplexity" (EDCHY) – here because this thesis is published before [26] – it should be filtered to serve it. Therefore, here EDCHY is regarded as the key problem able to be settled via BR as educational strategy. As a result, first the title must be explained: *Why Post-Modern?* (7.1.1) and *Why Chaoplexity?* (7.1.2). Further, the *first attempt to include bounded rationality in e-teaching* is outlined (7.1.3). Finally, it is shown that BR can be used as *antidote to educational chaoplexity* (7.1.4), i.e., as mechanism able to alleviate the temporal hiatus intrinsic to continuing education (3.3).

##### 7.1.1. Why Post-Modern?

The reasons why this fuzzy, chameleonic, misunderstood, misjudged, but essential concept is interpreted according to quotations from [162] will be given later (7.2.3):

"Postmodern and postmodernism is relating to art, architecture, literature, or thinking developed after and usually in reaction to modernism, returning to more classical or traditional elements and techniques. [...] In general, the postmodern view [...] tends to concentrate on surfaces rather than depths, to blur the distinctions between high and low culture, and as a whole to challenge a wide variety of traditional cultural values". In line with [162], in the EU2020 cluster the concept refers to [14]: "(1) a periodizing concept capturing this moment in human history which goes beyond-'past' this modern era and opens to a new period in human history; (2) the beginning and end of modernity [...] (3) the emergent, dynamic, changing perspective and intellectual movement that critiques and actually rejects the dominant mindset of the "modern" era; (4) the emerging postmodern mindset suggests there is no Truth, but multiple truths; [...]. Also it's hard to locate it temporally or historically,

because it's not clear exactly when postmodernism begins [...]. Postmodernist thinking involves re-thinking finding the places of difference within texts and institutions, examining the inscriptions of indecidability, nothing the dispersal of signification, identity, and centred unity across a plurivalent texture of epistemological and metaphysical knowledge production. [...]. In the postmodern understanding, interpretation is everything; reality only comes into being through our interpretations of what the world means to us individually. Postmodern thought is open to ideas that include multiple interpretations, stories, narratives, text and search for meaning and wholeness [...] Postmodernism relies on concrete experience over abstract principles, knowing always that the outcome of one's own experience will necessarily be fallible" [162].

Other connotations – including those from [162] – are not assumed in this thesis.

### **7.1.2. Why *Chaoplexity*?**

"Chaoplexic warfare draws on the study of nonlinear phenomena of self-organization to propose a radical decentralization of armed forces through the adoption of the network form. [...] Information remains the central concept, and in this sense chaoplexity is an outgrowth of cybernetics; but the focus on change, evolution and positive feedback breaks with the cybernetic pioneers' concern for stability" [24]. "The edge of chaos is the 'comfort zone' for complex systems. [...] Networks, information technologies, non-linearity, positive feedback, self-organization, emergence, and decentralization are the main characteristics of the Chaoplexic Warfare. [...] Complexity at the "edge of chaos" is the normal situation that the military must deal with. Indeed, the Armed Forces' recognition of this reality is far from representing a setback for the purposes of military transformation. Adaptation, which is the preferred attribute that this work proposes as the hallmark of military transformation, closely relates to the Armed Forces' status as a complex adaptive system. Cohen and Goch's theory of military misfortune establishes three basic kinds of military failure: failure to learn, failure to anticipate, and failure to adapt. Whenever all these three types of failure happen together, 'catastrophic failure' occurs" [27] (quoting also [25]).

Remarkably, the concept of chaoplexity permeated already domains much closer to psychology than warfare – even if in syncretic stage: "It will be taken as given that the entire apparatus of that heterogeneous body of theory and disparate findings we label, variously, as "chaoplexity", "dynamical systems", "emergence", and so on and discussed below applies to biological systems as it does to the realm dealt with in physics. Biology has many better claims for special treatment. First of all, there indeed are codes in biology, and the nascent science of biosemiotics is well-begotten. [...]. Thirdly, the nature of life does seem to invite a biological uncertainty principle, whereby the very existence of investigative devices at the nano level and smaller might require us eventually to specify at what scale the investigation is purely physics, rather than biology. This, of course, requires us to give an account, however tentative, of what life itself is" [58].



### 7.1.3. First Boundedly Rational Approach in Modelling E-Teaching

“To attain knowledge, add things every day. To attain wisdom, remove things every day”. This extra quote from “Tao Te Ching” goes far beyond preferring Lao Tzu to Aristotle because it suggests that: a) the disagreement between knowledge and wisdom is at least twenty-plus centuries old; b) the origin of this discrepancy is linked to incessant accumulation versus exclusion; c) teaching had to tackle this inconsistency even in the oldest cultures; d) the link between *wisdom* and *removing* in Eastern tradition is similar to that between *explanation* and *simplicity* involved by Occam’s Razor in Western tradition; e) both traditions honour the same “*Lex parsimoniae*”; f) in fact, that means that BR in its preterminological syncretism (4.1) is not just praised but is paramount as epistemic device in both traditions.

Hence, the idea to blend the key traditions into a synergistic leverage seems both appealing and archaic. Though, the title asserts the main newness of the EU2020 research approach based on BR because:

- BR is not anymore an elusive subconscious approach but an effective mechanism (as shown above, mainly starting from 4.2).
- E-teaching for continuing education is a comprehensively revisited concept (the new kind of teaching involved by lifelong learning is the kernel concept of [26] while the connotations of “e-“ are given in 7.2.1).
- As shown in [64]: “In short, applying BR in agent-orientation means to recur often to Occam’s razor and to implicit knowledge.
- It was applied in CSITAO research as abridged in 7.2.2.

### 7.1.4. Bounded rationality as Antidote to Educational Chaoplexity

The necessary and sufficient reason to promote BR as key remedy to educational chaoplexity – i.e., as cardinal mechanism able to alleviate the temporal hiatus repeatedly mentioned above – can be abridged as: BR is a psychologic, hence lasting, feature [26].)

Thus the background is set up for the “framework able to manage educational chaoplexity based on BR as common denominator of, mechanism for, and connection between the two facets of continuing education: e-teaching and e-learning” (third thesis objective).

On the other hand, as regards the newest EU2020 research, the even stronger emphasis on BR as medication is due to the focus on psychology ([62], [61]) as well as to the obvious research trend in the area of interest. (Indeed, among the most relevant work published in 2011 referring chaoplexity, a third refers also to education.) The main difficulty is that “sufficient reason” to tackle the problem does not entail always also “sufficient groundwork” to solve it. That is why both [62] (focused on BR as *means*) and [61] (focused on e-teaching as *ends*) aim at convincing psychologists to cooperate with computer scientists in devising the framework for continuing education.

Since cognitive psychology – as both phylogenetic achievement and corpus of knowledge – has a lower time derivative than the other fields/disciplines involved in continuing education, it should be the crux of any e-teaching project. A good starting point for setting

up such a foundation in the context of “human reasoning and cognitive science” is [81], where the following basic quotations come from: “results [...] purportedly showing the irrelevance of formal logic to actual human reasoning, have been widely misinterpreted, mainly because the picture of logic current in psychology and cognitive science is completely mistaken”. “Our first aim is to see to what extent the psychology of reasoning and logic (more generally, semantics) are relevant to each other. After all, the psychology of reasoning and logic are in a sense about the same subject, even though in the past century a rift has opened up between them”. “It is a fine irony that professors, of all people, should come to the view that conceptual learning is not a part of human nature, but merely a cultural oddity”. “At the educational level, there are questions about the level of transfer of the learning of classical logic to the students’ reasoning practices”. “Evolutionary psychologists believe that human cognition is in toto a product of adaptation. This claim may seem counterintuitive at first sight, since humans have impressive learning abilities. Certainly evolutionary psychologists would claim that learning abilities are also the result of adaptation and that they are composed of specialised learning abilities rather than generalised ones. The evolutionary psychologists’ view is that human cognition consists of a number of adaptations, which have been useful for survival at one stage or another”. “With very few exceptions [...], psychologists of reasoning have not asked what educational significance their results have. They regard their theories as investigating ‘the fundamental human reasoning mechanism’ which is independent of education” [81].

In short, both kinds of reasoning, *serial* (based on *binary* logic) and *parallel* (based on *non-monotonic* logics), must constitute the texture of any teaching endeavour dedicated to continuing education. Confining a kind of reasoning to a specific brain hemisphere is a rather acceptable oversimplification to start with. Unfortunately, cognitive psychology – while consistent and established – seems rather inappropriate as corpus of knowledge because of a predominantly deterministic (left brain hemisphere, serial, “von Neumann-like”) approach. Thus a paradigmatic shift based on the innovations brought by EU2020 research becomes urgent. The first is (only partially) outlined below.

## **7.2. E-TEACHING AS BOUNDEDLY RATIONAL (SUB)SYSTEM**

Before investigating “teaching”, it is useful to analyse the prefix “e-“ considering the quintessential and multiple role of e-teaching for two EU2020 theses (7.2.1). As very often, time is able to *split systems*: in continuing education *teaching* is performed *now*, whereas *learning* comes *much later* (7.2.2). Maybe *modelling teaching* needs also a prefix: *meta* (7.2.3). Thus, teaching could be able to *reunite the system*, *catalysing self-teaching* (7.2.4).

### **7.2.1. The Epistemology of a Prefix: “e-“**

Before revisiting the kernel concept of “teaching”, the connotations of “e-“ should be clarified. This is easy because “e-“ was studied in previous CSITAO research, in the context of an “example of a controversial ethical issue relating to an ethically

uncontroversial application within a sensitive domain: e-therapy” [9]. Moreover, in [9] the prefix and its – partial or debatable – synonyms are carefully compared: “[s]ince perspectives are sometimes vague or subconscious, they are mostly *implicit* and they can remain hidden, whereas concepts have to be dealt with, hence they must be *explicit*; [t]hese implicit, sometimes fuzzy, connotations associated with (especially new) concepts often result in confusions that can be harmful” [9]. Thus, the analysis made in [9] is abridged below also for reasons linked to continuing education:

“The first question of terminology is whether the term e-ethics is appropriate to describe the field under discussion here. The widespread prefix “e-” started as an abbreviation for “*electronic*”. Nowadays, it may be attached to anything that has moved from a traditional form to its ICT alternative (e.g. e-mail, e-commerce, e-business, e-government, e-learning, e-procurement). In other words and possibly oversimplified, “something available via the computer and the Internet”. The problem is that ambiguity appears when the prefix is used metaphorically (for instance, the term “eEurope” is confusing, since it is not an alternative, “electronic Europe”, as in the case of “e-mail”).

An alternative term that has been used in the literature is “digital ethics”. But using “digital” instead of “e-“ deserves a detailed commentary, since this too is problematic even if reflecting on its connotations is revealing. The first technological connotations of “digital” were “a set of discrete, distinct levels” or (at most), “a sequence of discrete, distinct steps enabling users to control an application or a device”. At a later stage in its semantic journey, “digital” describes electronic technology that encodes information in binary form (i.e. not as a continuous spectrum of values as in analogue representations). Since in computers the information is processed in both *electronic* and *digital* form, the terms could be used interchangeably when referring to ICTs. Moreover, “digital” is more accurate (semantically); therefore, old terms preserve the “e-“ (e.g. e-mail), while new ones use “digital” (e.g. digital divide).

However, further connotations of the word “digital” reflect the subconscious influence of an “anti-technology” mindset: whereas nature – humans included – has always been intrinsically analogue, the invading ICT has been digital and [...] was unable to interact with all its users through a totally analogue interface. While ICTs are now powerful enough to afford interfaces enabling users to interact with technology in their natural, ancestral, analogue manner, nearly forty years of manifestly digital ICT structures have induced the feeling that “digital” involves a kind of Frankenstein-like unnatural and dangerous feature (the next contrasting pair is more than enlightening in this respect: *electronic processing* versus *digital manipulation*). As a result, bad circumstances are more likely to get the attribute “digital”, while more palatable ones are characterised as “electronic”. The confusion reaches its pinnacle when old, amenable, common technologies progressed from an analogue form to a digital one, dramatically amplifying their performances. Now, “digital” is used reasonably in *digital camera* (because it replaced the old one, based on analogue technology) and acceptably in *digital television* (for the same reason). On the other hand, using the “digital” is debatable in *digital certificate*, ridiculous in *digital certificate authority*,

or in *digital privacy* and mystifying – even deplorable, given its current connotation – in *digital ethics*” [...].

“In a nutshell, nowadays the phrase “digital ethics” is faulty because, although it is not defined as such, it refers to *human* ethical behavior when using *digital* devices (or, more generally, ICTs). On the other hand, it is appropriate to refer to “eHippocrates” (in e-therapy) or to “eMachiavelli” (in e-commerce) as figurative alternatives to their historical counterparts. But, the term “e-ethics” is definitely debatable since it is not – or, it should not be – another type of ethics, just because ICTs are involved” [9].

### 7.2.2. Splitting the System: Teaching (Now) Vs. Learning (Much Later)

Separating the two parts – still in osmotical interference – of any educational process seems strange in research with assumed holistic perspective. In fact, it is rather a paradox of “holistic taking apart” since the two processes take place in different temporal frameworks – as shown in the title. The problem of “time as obstacle” was introduced in previous papers as “baffling paradox” of a temporal contradiction: “how to organize institutional *teaching*, clearly limited in both time [...] and objectives [...] to meet the expectations of a dynamic and indistinct environment, as implied by the concept of life-long *learning*. The inconsistency is deeply rooted in traditional perceptions about the educational process itself, seen as requiring a face-to-face relationship between teacher and student. Since it is obvious that the processes of teaching and learning cannot be anymore synchronous, with the student and teacher sharing knowledge in the same space and time, a totally new [...] approach is needed” [63]. In reality, “[h]ow can we assess the potential effectiveness of yet not born skills (i.e., the *quality* of learning) *measuring* (often just by grades) the volume of knowledge acquired by the students (i.e., the *quantity* of teaching)? Primarily in education, quality should regain its prevailing role in *evaluation*. (However, “At the beginning was the Word”, not the number.) [...] Universities must start a critical [...] revolution towards [continuing education]. [...] To be affordable, such a shift is beyond the reach of both traditional solutions and local approaches” [66].

For continuing education “e-” is not anymore a variant, it becomes a must: “The educator profile should move from teacher, to trainer, to moderator, to catalyst (because the target moves swiftly from knowledge to skills). [...] The “e-”prefix is inexorable (because of the “temporal contradiction”) [...] Acknowledging the huge hurdles in devising “e-teachers”, how could we expect to devise better “e-catalysts”? [...] How could be “computer-aided” an intellectual activity that is human-oriented *par excellence*? Here comes in [...] artificial intelligence: e-learning applications should be conceived as anthropocentric systems” [63].

Indeed, continuing education requires learners to become “educationally autopoietic”.

### 7.2.3. (Meta?)Model of e-Teaching

Why “meta-”? Because teaching (prefixed with “e-” or not, more or less already affected by the obvious crisis of institutionalised education) becomes increasingly chaoplexical. To bring evidence to this claim, a micro-case-study was carried out choosing an application space as significant as possible: teaching *nursing*. The quotations from [162] that follow

highlight the design-space metadimensions relevant for both the first metamodel of e-teaching and the setting of [62] and [61]: vital service, new skill-oriented and self-organizing profession, transdisciplinary – and yet syncretic – corpus of knowledge, intensely dynamic and almost totally uncertain environment, only qualitative validation, etc.: “The Science of Nursing moved from a deterministic to a postmodern philosophical approach without a transitional period”. “Jean Watson in "Postmodern Nursing and Beyond" wrote: "The art and science of human caring and healing can be considered in some ways auto-poietic; that is, it has been and is a discipline that is making itself". “Leading the vehicle of the Science of Nursing into the 21st century, nurses need to escape from the barren professionalism, from the critical pathways, from the mechanistic nursing process, in order to discover ourselves through the daily practice, creating through nursing actions as exactly as the artist to create new shapes or expressions of Nursing Art”. “Socialization into nursing profession is the understanding of the world from inside, from our perception, thought, practice and actions interacting with metaholistic knowledge, and resisting the strict fact and deterministic model of the structure of the Human Being”. “If anyone insisted on a deterministic approach to the changes described above, they would fail to adapt. The person using deterministic thinking pursues a vigorous analysis based on laws of foresight, of stability, and certainty, which result in a failure to adapt”.

A primitive *VISON* (*V*irtual *S*Ocratic Nurse) was described in [6] and used in [26].

#### **7.2.4. Reuniting the System: Catalysing Heutagogy**

In 7.2.2 teaching was separated from learning only *operationally* (because of the different temporal frames). Now their organic unity is restored firstly because previous CSITAO research proposed “*e-maieutics*” [5] as solution for adapting engineering education to a service-based society.

“While Malcolm Knowles contributed greatly to our understanding of the limitations of pedagogy when it came to adult learning by defining andragogy, [...] andragogy did not go far enough. [...] curricula were still [...] teacher-centric. [...] Action research allows experimentation [...] where learning is in the hands of the participants. [...] This is as close to real world learning as one can get in a controlled setting [...] [D]octoral students undertaking action research theses have progressed from pedagogical, then andragogical to heutagogical learning in [...] their research” [49].

In [65] “heutagogy AND metalearning” were investigated as implementation mechanisms for e-maieutics applied to continuing education: “to accomplish e-maieutics based [continuing education], heutagogy and metalearning should be blended: a) *intimately* (almost osmotically, to yield synergistic effects); b) *variably in time* (gradually increasing the spotlight on heutagogy); c) *unlike in perspective* (teachers focus on metalearning, whereas e-maieut focus on heutagogy)” [65].

As regards the need for agent-orientation, “[s]ince a maieutic process implies a “one to one” relationship, any e-maieut – conveyed or not through a pseudoavatar – must be architectonically an agent since it has to interact constantly with the learner [...]. As regards the subject matter of the *duologue* between a virtual Socrates and a real human, it

depends on the knowledge encompassed by the ontology they share [...]. In short, it is a chain of implications: [...] e-maieuts → complex and lasting interaction → intentional stance → interface agents. (Indeed, agents are available without timeout.)” [65].

In short: a) *architecturally*, heutagogy (as *strategy*) is continuing decision making; b) *structurally*, heutagogy (as *process*) is decision *in the* making; c) heutagogy without BR as *negative* feedback is *risky*; d) heutagogy without BR as *positive* feedback is *useless*.

Beliefs: a) transdisciplinary research based on intrinsic and deep similarity between these two concepts is essential for both continuing education and DSS; b) it will boost paradigm shifting, badly needed in both; c) as suggested in 7.3.4 and 8.1 memetic engineering cannot be ignored anymore in service-oriented software.

### 7.3. EXTRAPOLATING LASTING TOPICS. THE *GOLDEN RATIO*

In essence, to accomplish the first thesis objective (2.2.1), it must be proved that the major new role of BR as “educational mechanism” can be put into service due to its (anthropogenetic?) feature of “psychological stabiliser” (through negative feedback, 5.3.2, 5.3.3). The proof is done in three steps: a) choosing an interesting topic that was a “*fixed point*” in history (7.3.1); b) investigating its *memetic stability* that assure its usability (7.3.2); c) suggesting a *boundedly rational way to extrapolate* similar topics in e-teaching (7.3.3). Since such topics are prone to “anecdotal evidence”, an exercise in *self-recurring memetic engineering* seems welcomed (7.3.4).

#### 7.3.1. *Divina proportia* as “Fixed Point” in History

The telling, on-going, and triumphant journey of the “*Divina proportia*” is compiled abridged below from two sources: a modern general purpose encyclopedia [[http://en.wikipedia.org/wiki/Golden\\_ratio](http://en.wikipedia.org/wiki/Golden_ratio)] and a highly specialized mathematics-oriented resource [163], highlighting from a thesis stance some differences to be commented upon in 7.3.2.

“In mathematics and the arts, two quantities are in the golden ratio if the ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one. The golden ratio is an irrational mathematical constant, approximately 1.6180339887.[...] Other names frequently used for the golden ratio are the golden section (Latin: *sectio aurea*) and golden mean.[...] Other terms encountered include extreme and mean ratio, [...] medial section, divine proportion, divine section (Latin: *sectio divina*), golden proportion, golden cut, [...] golden number, and mean of Phidias [...]

At least since the Renaissance [...], many artists and architects have proportioned their works [...] to approximate the golden ratio – especially in the form of the golden rectangle, in which the ratio of the longer side to the shorter is the golden ratio – believing this proportion to be aesthetically pleasing. Mathematicians have studied the golden ratio because of its unique and interesting properties. The golden ratio is also used in the analysis of financial markets, in strategies such as Fibonacci retracement [...]

The golden ratio has fascinated Western intellectuals of diverse interests for at least 2,400 years. [...] Some of the greatest mathematical minds [...], from Pythagoras and Eu-

clid [...], through [...] Leonardo of Pisa and [...] Johannes Kepler, to present-day scientific figures such as [...] Roger Penrose, have spent endless hours over this simple ratio and its properties. But the fascination with the Golden Ratio is not confined just to mathematicians. Biologists, artists, musicians, historians, architects, psychologists, and even mystics have pondered and debated the basis of its ubiquity and appeal. In fact, it is probably fair to say that the Golden Ratio has inspired thinkers of all disciplines like no other number in the history of mathematics [...].

Ancient Greek mathematicians first studied what we now call the golden ratio because of its frequent appearance in geometry [...].

The modern history of the golden ratio starts with Luca Pacioli's *De divina proportione* of 1509, which captured the imagination of artists, architects, scientists, and mystics with the properties, mathematical and otherwise, of the golden ratio". [[http://en.wikipedia.org/wiki/Golden\\_ratio](http://en.wikipedia.org/wiki/Golden_ratio)].

On the other hand, the "ratio of the circumradius to the length of the side of a decagon is also  $\phi$  [...]. Exact trigonometric formulas for  $\phi$  include  $\frac{1}{2} \csc\left(\frac{\pi}{10}\right)$ . [...]

golden ratio is given by the infinite series  $\phi = \frac{13}{8} + \sum_{n=0}^{\infty} \frac{(-1)^{n+1} (2n+1)!}{(n+2)! n! 4^{2n+3}}$  [...]. Another fascinating connection with the Fibonacci numbers is given by the infinite series

$\phi = 1 + \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{F_n F_{n+1}}$ . " [163]. The problem is: who cares about exact trigonometric formulas or infinite series? Since the question is rhetoric only to a degree, it is worth further investigation (7.4.3).

### 7.3.2. Memetic Stability

Three memetic features of such topics should be focused on to ease applying them in continuing education: a) *lastingness* (they are a leitmotif in cultural history); b) *ubiquitousness* (they permeate all cultures); c) *effectiveness* (they are active now in education).

- *Lastingness*. The leitmotif feature was illustrated unquestionable in 7.3.1 but to prove the memetic nature evidence should be added as regards Lamarckian (rather than Darwinian) propagation – since genetic inheritance is excluded *ab initio*. Thus, the most relevant examples are from music because it is hard to believe that composers like Chopin have applied consciously such an "antiromantic method":

"The golden ratio is also apparent in the organization of the sections in the music of Debussy's *Reflets dans l'eau* [...] in which "the sequence of keys is marked out by the intervals 34, 21, 13 and 8, and the main climax sits at the phi position" [...]. Also, many works of Chopin, mainly *Etudes* [...] and *Nocturnes*, are formally based on the golden ratio. This results in the biggest climax of both musical expression and technical difficulty after about 2/3 of the piece" [[http://en.wikipedia.org/wiki/Golden\\_ratio](http://en.wikipedia.org/wiki/Golden_ratio)].

- *Ubiquitousness*. Likewise, the presence in nature is relevant from an epistemic perspective (see below) but here is culture that is essential – to eliminate possible genetic inheritance:

“Pacioli actually advocated the Vitruvian system of rational proportions. [He] also saw Catholic religious significance in the ratio, which led to his work's title. Containing illustrations of regular solids by Leonardo Da Vinci, Pacioli's longtime friend and collaborator, *De Divina Proportione* was a major influence on generations of artists and architects alike [...]. Many of the proportions of the Parthenon are alleged to exhibit the golden ratio. The Parthenon's facade as well as elements of its facade and elsewhere are said by some to be circumscribed by golden rectangles.[...] A geometrical analysis of the Great Mosque of Kairouan reveals a consistent application of the golden ratio throughout the design, [...] It is found in the overall proportion of the plan and in the dimensioning of the prayer space, the court, and the minaret. [...] Le Corbusier [...] centered his design philosophy on systems of harmony and proportion. [Hi]s faith in the mathematical order of the universe was closely bound to the golden ratio and the Fibonacci series, which he described as "rhythms apparent to the eye and clear in their relations with one another. And these rhythms are at the very root of human activities. They resound in man by an organic inevitability, the same fine inevitability which causes the tracing out of the Golden Section by children, old men, savages and the learned." [He] explicitly used the golden ratio in his Modulor system for the scale of architectural proportion. He saw this system as a continuation of the long tradition of Vitruvius, Leonardo da Vinci's "Vitruvian Man", [...] who used the proportions of the human body to improve the appearance and function of architecture. [...] Salvador Dalí [...] explicitly used the golden ratio in his masterpiece, *The Sacrament of the Last Supper*. The dimensions of the canvas are a golden rectangle. A huge dodecahedron, in perspective so that edges appear in golden ratio to one another, is suspended above and behind Jesus [...]. There was a time when deviations from the truly beautiful page proportions  $2:3$ ,  $1:\sqrt{3}$ , and the Golden Section were rare. Many books produced between 1550 and 1770 show these proportions exactly, to within half a millimetre. [...] Studies by psychologists, starting with Fechner, have been devised to test the idea that the golden ratio plays a role in human perception of beauty. While Fechner found a preference for rectangle ratios centered on the golden ratio, later attempts to carefully test such a hypothesis have been, at best, inconclusive. [...] Some sources claim that the golden ratio is commonly used in everyday design, for example in the shapes of postcards, playing cards, posters, wide-screen televisions, photographs, and light switch plates” [[http://en.wikipedia.org/wiki/Golden\\_ratio](http://en.wikipedia.org/wiki/Golden_ratio)].

- *Effectiveness*. Here the connotation is that of *viability* i.e., the meme is still alive and active in post-modern society, not that its use is recommended for agent-orientation or even for continuing education. However, in the golden ratio case the application proved to be so relevant that the instance is used as archetype for new e-teaching (just below).



### 7.3.3. Boundedly Rational Extrapolation in E-Teaching

“Interdisciplinarity has become increasingly important for emergent professions of the 21st century yet there is a dearth of systematic studies aimed at implementing it in the school and university curricula. The Mathematics and its Connections to the Arts and Sciences (MACAS) group places Mathematics as a vehicle through which deep and meaningful connections can be forged with the Arts and the Sciences and as a means of promoting interdisciplinary and transdisciplinary thinking traits amongst students. The Third International Symposium held by the MACAS group in Moncton, Canada in 2009 included numerous initiatives and ideas for interdisciplinarity that are implementable in both the school and university setting. The chapters in this book cover interdisciplinary links with mathematics found in the domains of culture, art, aesthetics, music, cognition, history, philosophy, engineering, technology and science with contributors from Canada, U.S, Denmark, Germany, Mexico, Iran and Poland amongst others” [56].

Choosing the golden ratio to carry out a modern, wide-reaching, interdisciplinary, and international educational endeavour is enough an (albeit anecdotal, 7.3.4) evidence to support the idea that the meme is active and of great consequence for education; moreover, its memetic stability ensures that such topics will be even weightier for *continuing* education. As regards the claim – crucial for the whole EU2020 research – that applying such topics in teaching is organically linked to BR, it is defended throughout this thesis mainly starting from 4.1.1 – but most explicitly in 7.1.3 and 7.1.4. Perhaps the most promising aspect substantiating this link in the Moncton experiment is that the incongruity between stability and creativity seems to vanish (7.2.4). Indeed, the golden ratio “can be found in many areas of mathematics and real life, including architecture, music, art, and nature and can be expressed in many different forms which may be surprisingly complex and interconnected. Very often, authors refer to this number as expression of beauty of our world. [...] its interdisciplinary nature combined with rich mathematical relationships make it attractive for teachers and students as it helps in building multiple connections between mathematics and other between mathematics and other subjects and real-life applications” [56]. Keeping on with stability (searching everywhere the same ratio) the children become creative (they make “surprisingly complex and interconnected” assumptions no matter of finding new instances of the ratio looked for).

### 7.3.4. Self-Recurring Memetic Engineering. What Time Is It?

In 7.3 – and in 7.4 even more – there is a “narrative touch” (why mentioning Vitruvius or Chopin?), hence the thesis is exposed from a standard scientific stance, because it uses *anecdotal* evidence instead of *scientific evidence*.

#### 7.3.4.1. How Scientific Is Still the “Scientific method”?

The defence of anecdotal evidence is twofold:

- a) *Claim*: “Scientific method” must be redefined to be relevant to service-oriented engineering. In its current connotation it is rather a vicious *meme* than an applicable *method*.
- b) *Belief*: the main cause for this intrinsic inadequacy is the (mis)perception of *time*.

The following quotes are only from Wikipedia (to be both *simple* and *hard to contest*): [wikipedia.org/wiki/{Scientific\_evidence, Anecdotal\_evidence,Scientific\_method, Empirical, Measurement#Definitions\_and\_theories, Statistical\_inference, Bayesian\_inference}]:

- “Anecdotal evidence, which may itself be true and verifiable, can be used to deduce a conclusion which does not follow from it [...]. The term is often used in contrast to *scientific evidence*, [...]. Some anecdotal evidence does not qualify as scientific evidence because its nature prevents it from being investigated using the scientific method”.

- “To be termed scientific, a method of inquiry must be based on gathering *empirical* and *measurable* evidence subject to specific principles of reasoning”.

- “Although procedures vary from one field of inquiry to another, identifiable features distinguish scientific inquiry from other methods of obtaining knowledge. Scientific researchers propose hypotheses [...], and design experimental studies to test these hypotheses via predictions which can be derived from them. These steps must be repeatable, to guard against mistake or confusion”.

- “Given a parameter or hypothesis about which one wishes to make inference, statistical inference most often uses: \*a statistical model of the random process that is supposed to generate the data, and \*a particular realization of the random process; i.e., a set of data”. [...] The conclusion of a statistical inference is a statistical proposition. Some common forms of statistical proposition are: \*an estimate; i.e., a particular value that best approximates some parameter of interest, \*a confidence interval (or set estimate); i.e., an interval constructed from the data in such a way that, under repeated sampling of datasets, such intervals would contain the true parameter value with the probability at the stated confidence level, \*a credible interval; i.e., a set of values containing, for example, 95% of posterior belief”.

- “Bayesian inference is a method of statistical inference in which evidence is used to update the uncertainty of probability models. [...] [It] is often used to make predictions about the value of model parameters and unknown variables and to perform model selection”.

- “To evaluate the probability of a hypothesis, the Bayesian probabilist specifies some prior probability, which is then updated in the light of new relevant data”.

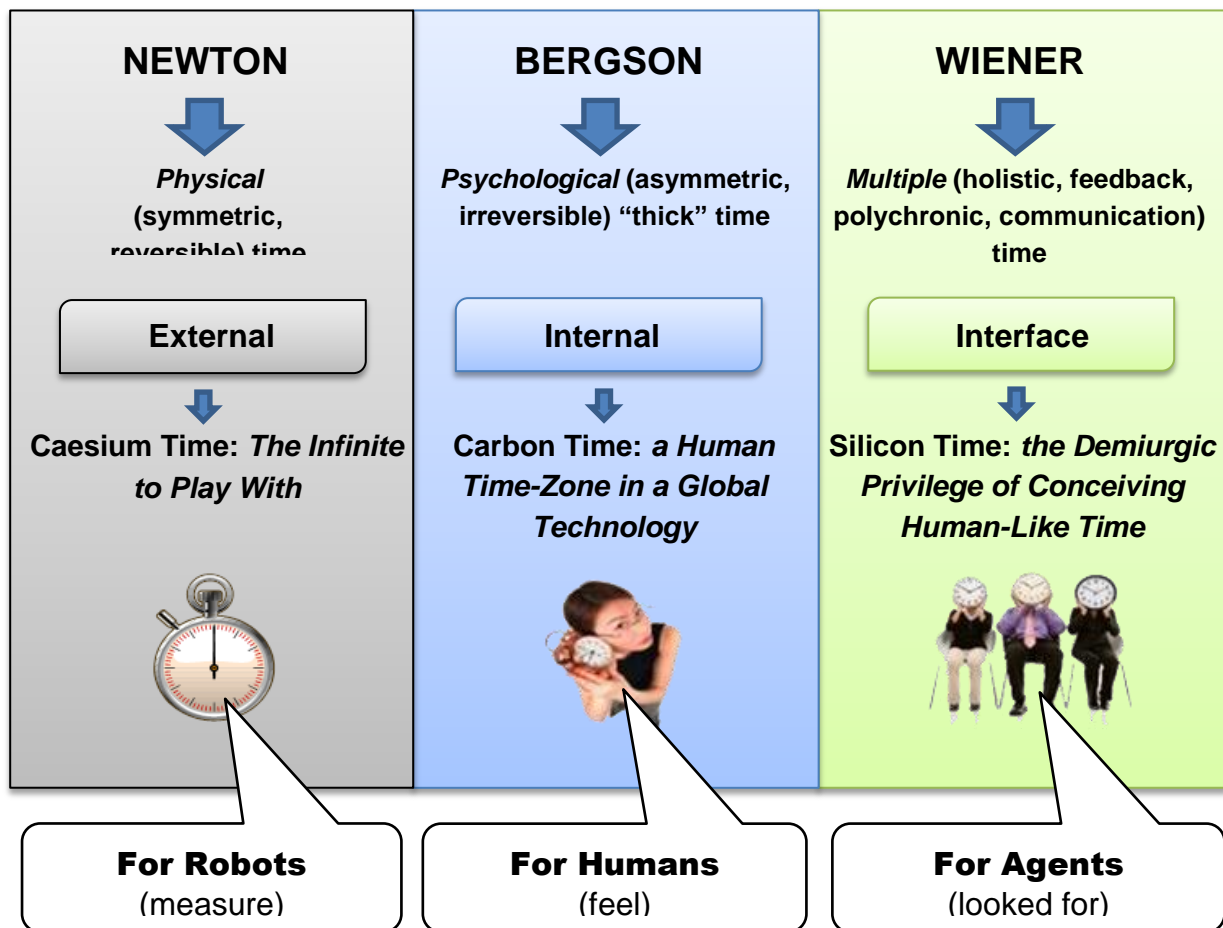
In short, using in the very foundation of “Scientific method” terms or syntagms like “repeated sampling”, “posterior belief”, “predictions about”, “prior probability” involves a particular perception of time. This perception *is not* – and could not be – *the same* for scientists of the main disciplines involved, because their very concepts of time are deeply divergent. Thus, they do not *measure* the time they *perceive* and vice versa. Comments below.

#### **7.3.4.2. “Machine” or “Test”? Same Turing but different meanings of time in “return-1”**

It seems strange that, in spite of being the brainchild of the same father, the Turing *machine* and the Turing *test* are treated differently: in Control engineering the test is – of course – ignored, while in AI (where the test was aimed at) the interest is still focused on the *deterministic algorithm*, not at all on the *nondeterministic dialogue* involved by the test

(nobody investigates what is in fact tested and what tools are used; worse, the test is often mentioned but almost never used).

The stances are expressed linking the meaning of “return” in C/C++/Java-like programs (6.3.1, 6.3.4) to the tacitly accepted perception of time (Figure 7.1). For the sake of conciseness, the working concepts in [12], [8] are kept without commenting upon: “Physical (“Caesium Time”, *TCs*), Psychological (“Carbon Time”, *TC*), Agent (“Silicon Time”, *TSi*)”.



**Figure 7.1.** Three ideas of time, Bayes was unaware of (abridged and adapted from [8])

- *Automatic Control.* Time is Newtonian (*TCs*): linear, infinite, symmetrical (reversible), precisely measurable via its inverse magnitude (frequency measured by crystal oscillators:  $2^{15}$  Hz). Infiniteness is emulated through circularity. “A useful tool [...]: the simple loop, offering the “Infinite in Time” to play with” [8]. It was applied everywhere in “clocks”, recommencing a measuring cycle (e.g., naturally in sundials, renewing the water supply in clepsydrae or electric energy nowadays). Likewise in the history of cultures: reincarnation, “*éternel retour*” (from Nietzsche to Eliade), Mayan calendar (even the “2012 Doomsday” is just the end of a *cycle*, not the end of the *world*). Here the Turing-machine-based definition of *algorithm* is slightly distorted: “*return*” is valid *ad litteram*, in its initial meaning of returning from a callee (the loop body) to the caller (the program entity where the loop is carried out). Nevertheless, within the callee the algorithm is undistorted: “*return*” means “*halt*”.

- *CSIT* (product-oriented). Time is linear and infinite in theory. In practice time is expressed by algorithmic sequentiality, in a manner similar to that described for the callee: “return” is synonymous with “stop” or “exit” meaning “halt”.

- *AO* (process-oriented). Time is Bergsonian (*TC*): linear, infinite, asymmetrical (irreversible). Perhaps Husserlian too (“thick time”). Any service provider – natural or virtual alike – must have a similar time (*TC* or *TS*). Hence, “return” means reporting after the service is finished: if successfully then “return 0”, else “return -1”. Cognition, decision making, nursing, learning, and so on are *processes* requiring *TC*. Any algorithmic modelling based on *TCs* is pointless – except when performed by automata.

All explanations, approaches, examples, and warnings stemming from Carrell [65], Wiener [12], [8], Gigerenzer [127], [128], [129], or other leading 20th century scientists are underestimated. Worse: a) mathematicians practically ignore the problem: “Mathematics is atemporal (nobody was fired because Fermat’s Last Theorem was proved only after more than three centuries!)” [16], [64]; b) psychologists and computer scientists model “user profiles” based on statistic (or even Bayesian) methods (strangely, nobody tried to model an “infant profile” for teaching the mother tongue!).

Corollaries: a) investigating “the time memplex (*Tx*, based on memetic engineering)” [8] is urgent because the memes suggesting that post-industrial high-level software (e.g. DSS, e-Teaching) can still be algorithmic become vicious, disregarding basic human features; b) as in most cases of paradigm shifting, memetic engineering can be applied in a first phase only in its primitive form used in this thesis; c) transdisciplinarity is mandatory; d) until refining the “scientific method”, ostracising anecdotal evidence is counterproductive.

(An example of “reverse memetic engineering”: one of the greatest producers of imaging and optical products used successfully fuzzy technology in cameras, but avoided it in advertising because – meme or not – “fuzzy camera” could be linked to “blurred image”. The sentence is in parentheses because the evidence is “100% anecdotal” (*sic!*): I heard it from my advisor, he heard it from Zadeh, Zadeh gave no proof whatsoever – in spite of being neither “off camera”, nor “in camera”.)

## **7.4. EXTRAPOLATING ANCIENT BEHAVIOURS. THE *DAMASCUS* *BLADE***

Even without prior knowledge of psychology, it is well-known that behaviours are extremely lasting. Hence, they can illustrate the role of BR as “educational mechanism” much more convincingly than widespread topics – albeit very famous ones (7.3). The three steps are similar to those above: a) choosing the pervasive habit of *scoring* (instead of counting) (7.4.1); b) investigating the related *innumeracy memplex* (7.4.2); c) proposing a boundedly rational way to exploit simplicity in e-teaching based on not numerical mathematics (7.4.3), therefore, 7.4.3 becomes a call to teamwork (for [26] it is vital); d) preparing a more general and more inclusive extrapolation: from “Homo Algorithmicus” to “Homo Logarithmicus” (7.4.4).

### 7.4.1. In (Pre)History Scoring Was Easier

Easier than what? Scoring was – and still is – certainly easier than *counting*. But, is it easier than *any measuring* too? The narrative of the Damascus blade (even nowadays blend of legend and unexplained facts) was chosen not just because it is linked to a prehistoric and commonplace meme (details in 7.4.2) or because it is motivating (through serendipity it proves to be interesting as topic too, since the technological enigma is yet unsolved). There are at least other six reasons why scoring is relevant for BR as teaching mechanism: a) the informal experiment referred to in 5.1.2 showing the frequent epistemic problems as regards the relationships between “scoring”, “comparing”, “measuring” and so on; b) it is independent on technology: both the ancient blacksmith (without high precision thermometer) and the present-day oncologist (with high-tech Japanese elastograph [18]) just compare colours; c) moreover, both use their eyes as “high precision equipment” in evaluating hue after transducing; d) corollary: is it another example of shifting from myth to meme (or the other way around?) e) it opens significant transdisciplinary niches towards *semiotics* in at least two directions: nonverbal communication (reflected primitively in the experimental model, 8.1, 8.3.5) and psycholinguistics (outside the scope of current research, maybe an open problem for [26]).

Obviously, behaviour has a much richer (pre)history than any topic – despite how famous it could be. Indeed, the “Fixed Point” approach in 7.3.1 could diminish the relevance tending to transform the substantiation into a pure narrative. The new, much more focused approach is based on etymologic evidence because it is: a) highly relevant; b) osmotically linked not only to BR but to “Just-in-Time” too; c) a lever for advancing the shift towards the fifth thesis objective (2.2.1, 5.4.3); d) a lever for “applied transdisciplinarity” (3.2.3.1, 3.2.4.1, 5.1.2, 5.2.4, 7.1.4, 7.3.3); e) a rich source of serendipity (7.4.3, 7.4.4).

All quotations below are from [<http://www.thefreedictionary.com/>] starting with “score”:

“A notch or incision, especially one that is made to keep a tally. [...] A usually numerical record of a competitive event: *keeping score*. [...] The number of points attributed to a competitor or team. [...] A ground; a reason. [...] A group of 20 items. [...] **scores** Large numbers [...] The notation of a musical work. [...] (Music) arrange, set, orchestrate, write, adapt, compose. [...] **settle a score** (*Informal*) [...] get even with someone (*informal*), give an eye for an eye [...] a number or letter indicating quality”.

The semantic etymon is: “Old English *scoru*, twenty, [...] *scora*; related to Old Norse *skor* notch, tally, twenty”. Before exploiting below the semiotic traces in the related memes, just three introductory comments:

- Remarkably, the etnolinguistic environment of this thesis endorses the etymologic evidence: Romanian “*răboj*”, “*zgâria*”, “*scrie*” or/and German “*Kerbholz*”, “*schreiben*”.
- Etymology is urgent for transdisciplinary undertakings and could become a pillar of memetic engineering.
- Moreover, CAS (2.3.1) as application domain of CSITAO gets new support.

### 7.4.2. The Innumeracy Memplex

Both keywords in the title bewilder because they are yet syncretic neologisms (defined in [14], referred to in 3.2.4, 7.3.2).

“Innumeracy is a neologism coined by analogue with illiteracy; it refers to a lack of ability to reason with numbers. The term [...] was coined by [...] Hofstadter and popularized by [...] Paulos [...] Possible causes of innumeracy are poor teaching methods and standards and lack of value placed on mathematical skills. Even prominent and successful people will attest, sometimes proudly, to low mathematical competence, in sharp contrast to the stigma associated with illiteracy” [<http://encyclopedia.thefreedictionary.com/innumeracy>]<sup>8</sup>.

As regards the concept of *memplex*, to relate the concept to e-teaching, some new aspects of memetics should round out the investigation in 3.2.4: “It is not possible to get matter out of nowhere, but it is possible to get information, or new patterns of matter, apparently out of nowhere by making copies. If the copies vary slightly and not all the copies survive, then the survivors must have something that helped them win the competition—using Darwin’s term, they are more “fit”; they make a better fit to their environment. Then they pass on this advantage to the next generation of copies. [...] This is the fundamental idea that Richard Dawkins explained in his 1976 book *The Selfish Gene* [107]. He emphasised the importance of thinking about evolution in terms of information rather than squishy living creatures, and he called the information that is copied the replicator. In fact “replicator” is not a very good name, implying that it is the thing that does the replicating rather than being the thing that is replicated, (perhaps “replicatee” would be better)” [20].

On this groundwork it becomes clear that: a) from a memetic perspective *innumeracy* is inseparable from *illiteracy* (etymologic evidence below); b) despite their unbreakable bond they are distinct in real-world situations (to “reason with *numbers*” is much more difficult than to “reason with *letters*”; c) both stances are vital for teaching – prefixed with “e-“ or in any traditional clothing (7.4.3).

Remarkably, linguistics extends the scope of the memplex (the quotes below are from [<http://www.thefreedictionary.com/>]):

“*Scribe* [...] Middle English, [...], from Latin, keeper of accounts, secretary, from *screre*, to write; see *skrbh-* in Indo-European roots”.

“*Robot*” [...] Czech, from *robota*, drudgery; see *orbh-* in Indo-European roots [...] The Slavic root behind *robota* is *orb-*, from the Indo-European root *\*orbh-*, referring to separation from one’s group or passing out of one sphere of ownership into another. This seems to be the sense that binds together its somewhat diverse group of derivatives, which includes Greek *orphanos*, “orphan,” Latin *orbus*, “orphaned,” and German *Erbe*, “inheritance,” in addition to the Slavic word for slave mentioned above. Czech *robota* is also similar to another German derivative of this root, namely *Arbeit*, “work” (its Middle High German form *arabeit* is even more like the Czech word). *Arbeit* may be descended from a word that meant “slave labor,” and later generalized to just “labor.”

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<sup>8</sup> Unfortunately, I read about Paulos’ work too late to be able to assimilate it at the level involved by this thesis; hence it is postponed to future work (9.3).

Of course, to the Romanian “răboj”, “orb”, “orfan”, and “rob” some interesting links (9.3.1) could be added (and followed): “rubedenie”, “răbda”, and so on.

### 7.4.3. Extrapolating Comparisons and Ratios, Not Numerical Mathematics

In fact, some steps in this direction - substantiating the conceptual preeminence of *words* over *numbers* and endorsing BR as effective *cognitive tool*– are visible in the mechanisms proposed (e.g., the word-based bar for non-algorithmic input, 6.2) or in the experimental model (e.g., the toy problem, 8.4). On the other hand the first rough idea of a boundedly rational IT framework for holistic cognition and a first (meta?)model for continuing education (focused on e-teaching) are given in [26]. Thus, below are some stem cells for future work:

- *Memetic is not (just) mimetic.* “[P]hylogenetic or 'tree thinking' provides another way of Darwinizing culture that does not require a commitment to problematic aspects of memetics such as particulate cultural inheritance and tidy lineages of directly copied replicators” [48]. Thus, a speculative “Selfish meme” [11] is not necessarily just a software version of Dawkins’ “Selfish gene” [107].

- *Lamarck instead of Darwin.* In line with 3.2.4 and 7.3.2, e-teaching should consider “software epigenetics” based on Lamarckian propagation. Indeed, there is (indirect) evidence that Haeckel’s recapitulation theory holds in memetics too: the ontogeny of boundedly rational behaviour summarizes its phylogenic development, tremendously speed up by Moore’s Law *and* by the positive feedback of a chaoplex globalization. On the other hand, “In 2003, Volkmar [...] and Harald Weiss analyzed psychometric data and theoretical considerations and concluded that the golden ratio underlies the clock cycle of brain waves. [...] In 2008 this was empirically confirmed by a group of neurobiologists” [[http://en.wikipedia.org/wiki/Golden\\_ratio](http://en.wikipedia.org/wiki/Golden_ratio)].

- *Why is BR crucial for education?* Because it is a psychological – hence, lasting – feature, while education – above all continuing education – needs two divergent (if not contradictory) macrofeatures: *stability AND creativity*. As shown in 5.3.3 related to the golden ratio, BR seems able to show at the same time both feedback facets: the negative when *searching*, the positive when *finding*. (The paradox is even more challenging when BR is related to behaviours based on the deep relationship between BR and “Just-in-Time”.)

- *Transdisciplinary Knowledge.* The golden ratio is again an archetypal instance since: “it can be found in many areas of mathematics and real life, including architecture, music, art, and nature and can be expressed in many different forms, which may be surprisingly complex and interconnected [56].

- *Not Numerical Mathematics.* Except very abstract aesthetical reasons, not even passionate mathematicians would prefer the exact trigonometric formulas for the golden ratio presented in 7.3.1, to the (boundedly) rational appearance as *relevant geometric ratio* or as quotient of successive Fibonacci numbers (since here time is intensely involved, this aspect needs comprehensive future research, 9.3).

- *High propension to comparisons.* It is worth a separate investigation (7.4.4). Focusing further, comparisons substantiate the fifth thesis objective (2.2.1, 5.4.3), as shown below.

- *Semiotics*. “Der Begriff "Rechnen" lässt sich aus dem indogermanischen »reg« ableiten. Es bedeutete ursprünglich so viel wie »in Ordnung bringen«. Der Umfang einer Menge, z.B. eine Viehherde, konnte durch Zählen bestimmt werden. Auch im Mittelhochdeutschen bedeutet der Ausdruck "rech(en)en", im Althochdeutschen der Ausdruck "rehhanon" so viel wie »in Ordnung bringen« oder »ordnen«. Rechenprozesse sind demnach Ordnungsprozesse [...] Die Bezeichnung "Rechner" für einen Computer beruht auf der Tatsache, dass er viele Aufgaben durch binärarithmetische Berechnungen in sehr hoher Größenordnung löst. [<http://de.wikipedia.org/wiki/Rechnen>].” This research diRECTion (see also Rex, Recht, reglage, and so on) is not the only arrived at through serendipity.

An indisputable example of the deep links between semiotics and paleo-mathematics is the Romanian expression “la țanc”, proved to have – besides its adequacy, shortness, and amazing memetic stability – some captivating attributes: a) It is linguistically directly related to BR because “țanc” means in the old “mioritic” language “gauge”, “yardstick”, “benchmark” being used by milkers at the sheepfold to measure fresh milk. b) Albeit its etymology is yet uncertain, it is highly probable that the term comes from the Dacian substratum of the Romanian language; if so, it should be the first substratum-based term that enters not only the IT idiom but probably the Romanian scientific terminology altogether.

In short (as regards 7.4 and somehow the whole chapter too), to be efficient – in any intellectual endeavour but above all in teaching - the role of numbers should be weakened whenever it promotes simplicity – however not on every occasion (indeed, innumeracy is almost always both possible and dangerous).

#### 7.4.4. From “Homo Algorithmicus” to “Homo Logarithmicus”?

What means “user-oriented section” (6.2.5) in a “service-oriented thesis”? The quote from [32] in 6.2.5 includes (historical) information to emphasize that: a) mathematics had a meandrous entry into psychophysics; b) the *logarithm* has a paramount role in nature, humans included (mirrored also in CSIT through the basic *information theory* of Nyquist, Hartley and Shannon); c) moreover, its close related *exponential* and *sigmoid* functions had a crucial impact upon CSITAO research (for instance in stigmergic *self-organisation* [16]); d) focusing the emphasis on EU2020 research, the *sigmoid* is essential for emergence in chaoplex environments [26]; e) *comparisons* show to be deeper linked to BR than expected a year ago and yet not enough studied (6.2.5, 9.3)

In this context “user-oriented” means a *caveat*: in services involving cognition (e.g., DSS for high-level decision making or e-teaching for continuing education) information should be presented in an outer shell most palatable for the boundedly rational end user. Thus, if previous qualitative validation of similar services evidenced that comparisons expressed using *logarithmic functions* get more approval than measurement results or methods expressed using complicated formulae – the examples in 7.3.1 are more than unpleasant for a learner trying to understand the golden ratio – the “scientific method” should be replaced with “anecdotal evidence” without worrying about numbers and



deductions. (Indeed, *user* acceptance is more important than *academic* acceptance – above all when vital decisions are needed “Just-in-Time”.)

Returning to Lao Tzu, an exciting research opening could be added to this pragmatic stance: the “yin-yang symbol that out pictures the primordial emptiness ground [...] in whom arises these two primordial energies, yin and yang” [21] is “organoleptically” a sigmoid. Moreover, it suggests both sigmoid and linear nonseparability – the very message of the well-known pictogram. Of course, it is just a metaphor – albeit a very powerful one. Or is it something more than a polyvalent archetypal symbol? This fascinating question is totally outside the scope of this thesis but is worth a future investigation (9.3.1). By (professional) mathematicians, not by (dilettante) computer scientists.

## EIGHTH CHAPTER

### Implementing the Experimental Model for Visual Patterns

*Streben wir nicht allzuhoch  
Hinauf, dass wir zu tief nicht fallen mögen*  
SCHILLER "Wallenstein"

First the atypical, *service-oriented model validation* is dealt with, outlining its *rationale, features, and consequences* upon the experimental model (8.1). Then the two *non-algorithmic mechanisms* designed in Chapter 6 are applied in the model: the *word-based bar for simple but urgent decisions* (8.2) and the *decision-making framework to service-oriented dialog* (8.3). Now, the mechanisms are *merged in visual pattern recognition problems* (8.4).

#### 8.1. SERVICE-ORIENTED VALIDATION. RATIONALE, FEATURES, CONSEQUENCES

After summarizing the *basic difficulties of quality management in a service-based society* (8.1.1), *qualitative validation and its variants applicable* to the mechanisms and toy real-world problems put forward by this thesis are presented (8.1.2). On this basis the subject extensions as regards the experimental model are justified: *visual patterns* instead of *e-teaching* (8.1.3) and *visual patterns as a whole* instead of *visual pattern recognition* (8.1.4).

##### 8.1.1. Quality Management in a Service-Based Society. Basic Difficulties

The topic is abridged and adapted after [68], because it seems to have been “the first Romanian project to apply agent-oriented paradigms in open, uncertain and dynamic industrial environments; [...] it appears as one of the first European attempts to adjust quality management to the Knowledge Society, via agent-orientation” [65].

The major problems related to quality – dangerously amplified for a post-industrial (mainly service-based) society [60] are:

- “*Quality is hard to measure*. This hurdle is intrinsic to quality as being in fundamental conceptual opposition to quantity. However, in line with the reigning paradigms, the issue was approached in a reductionist manner, based on components described by “quality indicators”. Thus, the solution was paradoxical: most such “indicators” [...] assessed in fact either quantitative performance ([...] petrified in specifications set up (long) before beginning the production process) or genuine qualitative performance but applying debatable means (for instance, statistical methods even when no significance is expectable)” [68].

- “*Quality is highly contextual*. When production shifted from goods towards services [...] it became obvious that the significance [...] of the humans involved as beneficiary of

the service (or simply end-users of the good) is prevalent from all perspectives that matter (marketing, ergonomics, quality of life, and so on). However, opinions are intrinsically context-dependent (including elusive aspects like prejudice, mood, personality, habits, etc.) From a pragmatic stance, the shift in quality management began when anthropocentric systems entered industrial enterprises” [68].

- “*Quality is hard to describe*. [L]ike almost all process features – quality should be considered a function of time. However, how could a user evaluate the quality of a service when *past* quality becomes suddenly irrelevant, *present* quality is elusive, and *future* quality is unpredictable? Even worse: since most processes to be assessed are intended to be *services* – and are perceived as such by their end users – quality can be estimated only holistically. Hence, conventional quality indicators remain relevant only for macroprocesses [...] where statistics is applicable in general and case studies are comprehensive” [68].

“[T]o manage the rather fuzzy, subjective, and elusive quality of [...] services, there are two directions to follow: adopt *anthropocentric design* (to improve quality *per se*) and accept *qualitative validation* (to assess quality in a more relevant way)” [68], [60].

### 8.1.2. Qualitative Validation in Engineering and Its Variants Applicable in This Thesis

“Lord Kelvin, in line with the “Scientific Zeitgeist” of the nineteenth century (tailored mostly by him), claimed: “When you can measure what you are speaking about, and express it in numbers, you know something about it”. Hence, qualitative validation had mostly a “second-hand-like” nuance (in IT applications, sometimes even a pejorative one)” [68].

As regards qualitative validation: “How do we measure human-centeredness? Since anthropocentrism entails shifting from quantity (testing the *technological efficiency* of the application) to quality (validating the *target-oriented effectiveness* of its actual use), focus shifts from “building the *system right*” (“white-box testing”, in line with *specifications*) toward “building the *right system*” (“black-box testing”, in line with *ergonomics*) [150]” [68].

Paraphrasing the paraphrase [93] of Dertouzos’ query [109] the essence lies in a question (and the trouble in its answer): “What is the horsepower of your interface?” (In [26] it is even more chaoplex: “What is the horsepower of your e-teaching agent?”)

In other words, a defensible experimental model must be at the same time *concept-driven* (since it is *model* in *PhD research*) and *context-tailored* (since it is *experimental* in *Engineering Sciences*). That means a delicate balance between a credible validation and a “Just-in-Time” implementation. The four degrees of qualitative validation are:

- *In vivo*. In engineering sciences it involves R&D, since the entity to be validated – namely the model of a product or service – must be *repeated* in the real world (more or less identically) after each instance was *accepted* by its addressee. In the case of PhD research it is out of the question.

- *In vitro*. Involves a closed, controlled, and simplified “real-world fragment”. Thus it is possible only in incremental research. For exploratory research it is almost a contradiction in terms: exploration can be neither *controlled*, nor *repeated*.

- *In embryo*. Is appropriate for new mechanisms *iff* they are integrated in the implemented model itself (8.1.3, 8.4).

- *In ovo*. Is the minimal level of validation. Hence, it is mandatory for any experimental model. Corollary: the model must be carried out at the limit of resources (6.1.3, 8.1.3).

### **8.1.3. Why *Visual Patterns* Instead of *e-Teaching in Continuing Education*?**

The question was dealt with throughout this thesis from the very beginning (the fourth objective) from various angles, the two basic reasons being: a) lacking yet a conceptual model for e-teaching in continuing education, any credible validation was impossible (mainly in 2.3.4); b) the necessary pre-eminence of architecture over structure in any human-centred endeavour – first of all in exploratory research (mainly in 2.4.2). However, there are also less explicitly stated reasons – or better said, exploitable benefits of the new domain – that are worth to be mentioned:

- *Promoting the fifth objective*. Obviously, the instances of all three echelons of communication modalities shifting from *mathematics* towards *semiotics* (nonnumeric, nontextual, nonverbal, 3.2.3.2, 5.4.3, 6.1.2) are easier to illustrate, defend and validate within a simpler experimental model, where “simpler” means explicitly bounded rational, illustrating convincingly the band between BR and JIT.

- *Highlighting the thesis pillars: bounded rationality and “Just-in-Time”*. It would have been rather strange fighting structural complexity inside a chaoplex model (3.3). For instance, the e-teaching agent would have required a very demanding transdisciplinary word-based ontology with operational temporal dimension.

- *Socratic Duologue*. Even more difficult since there are two boundedly rational agents sharing in intensive interaction the same ontology “Just-in-Time” (5.4.3, 5.4.4).

- *Familiarity*. Besides the benchmark problem (2.3.4, 3.1.2, 3.5.1), the very domain of visual pattern recognition is seen likewise from both paradigmatic perspectives – in spite of the fixed idea that pattern *recognition* involves *clustering* achieved via artificial neural networks. (Indeed, it is weird to link an essential *human* feature to an *algorithmic* procedure.)

Other aspects related to the experimental model domain are mentioned below.

### **8.1.4. Why *Visual Patterns* Instead of *Visual Pattern Recognition*?**

On the contrary to the restrictions above, expanding the model from mere recognition to the most challenging domain of visual pattern as such is due to serendipity, promising but not fine-tuned as research (as a result the thesis title was not modified accordingly). The main conceptual scope extensions are due not only to the fifth objective of this thesis but also to [26] and are here clustered to defend the extension and the paradigm it serves:

- *Authentic Pattern Recognition*. The apparently pleonastic qualifier “*Authentic*” is necessary to delimit the model and its implementation from any link to Artificial Neural Network-based clustering (6.3.4, 8.1.3). In fact it is not even always visual (e.g., when information about service features is got by spoken language. (Though, “Visual” is withdrawn only in [26] because of insufficient model development.)

- *Pattern Designating*. In usual (face to face) communication it means “to point at” clearly enough that the interlocutor (biologic or virtual alike) should “reCOGNize” the pattern aimed at. In CSIT jargon it means: assigning to a linguistic variable a value from the set of constants applicable in the given context.

- *Pattern Demarcating*. Similar but distinct: delimiting a spatial region on an image clearly enough that the application should be able to assign unambiguously a value from the set mentioned above.

- *Pattern Processing and Transmission*. Albeit structural detail, it must be mentioned because of its role in validating the model.

All “*Pattern X*” features are illustrated in the model – some of them in yet primeval form.

## 8.2. APPLYING WORD-BASED INPUT TO SIMPLE BUT URGENT DECISIONS

In line with the new paradigm the toy problem is *defined* via its architectonic *attributes*, not *specified* via its measurable *constituents* (8.2.1). Based on these service macrofeatures, the *design space* is outlined (8.2.2) and instantiated for *the first prototype* (8.2.3). Now *implementing the (pseudo)linear-bar instance* is straightforward (8.2.4).

### 8.2.1. Defining a Child-Care Toy Problem: Fever Checking

For the sake of clearness, the well-known problem chosen to illustrate the mechanism is not described. Instead, its suitability is revealed in the light of the features sought for:

- *Bounded rationality*. Decision making is simple in both situations: “manual control” (a mother with her child in vacation, does not need thermometer, tacit knowledge suffices) and “automatic control” (in intensive care, no need for a nurse to ring the bell).

- “*Just-in-Time*”. Archetypal for “Rationale 4” (2.2.2, 6.2.3).

- *Holistic, non-algorithmic decision making*. The mother is her own “interface agent”, tacit knowledge is non-algorithmic *par excellence*.

- *Semiotics-based*. The presence of numbers could be delusive (what-if using Fahrenheit thermometer?) *Telling* (sic!) are the *concepts* the choices/actions are based upon.

- *Genuine Zadehian Fuzziness*. In spite of health being a very fuzzy (and context-dependent) concept, no human decision-maker needs triangular norms (or worse, fuzzy probabilities!) for fuzzification. Besides, concepts are just a few (in line with the “5 +/- 2” rule of cognitive ergonomics).

- *Seed of Psycholinguistic Expressiveness*. The multimodal perception (here the use of colours) lessens the logocratic pressure of concepts needing some natural language (a first step from “Computing with *words*” towards “Computing with *images*”).

- *Multifunctionality*. The modular design illustrated in Figure 8.1 is meant to allow the same design to be used for a variety of linguistics variables (e.g., beliefs expressed as certainty factors [92]). Obviously, the bar is labelled as “(pseudo)linear” because the “magnifying factor” is adapted to the (subjective) importance of the temperature interval. Therefore,

the “bar fragments” are concatenated in the experimental model interface (no thermogram is “split into pieces”).

- *Successive prototyping*. Corollary of the above.

### 8.2.2. Design Space

Any mechanism design-space has to be a subspace of the general design space of the application domain it is aimed at. The design space for post-industrial decision making is adapted from [5] and [6] because: a) the close relationship between e-maieutics and e-teaching<sup>9</sup>; b) nursing is archetypal for both decision making and “Just-in-Time” teaching (4.3.1, 7.2.3); c) *VISON* (*VRtual SOcratic Nurse*) was the first protoagent based on nondeterministic software and BR [6].

The most general design space for a **Service-Oriented Decision-Making Application** (SODMA) using a *Socratic* interface agent is a subset of the Cartesian product:

$$\mathbf{S}_{\text{SODMA}} = \mathbf{S}_{\text{SO}} \times \mathbf{S}_{\text{DM}} \times \mathbf{S}_{\text{Socrates}}$$

where for this thesis and the EU2020 research cluster

$$\mathbf{S}_{\text{Socrates}} = \mathbf{S}_{\text{maieutics}} \times \mathbf{S}_{\text{agents}}$$

and

$\mathbf{S}_{\text{SO}} = \{\textit{nondeterministic\_behaviour}, \textit{parallelism}, \textit{qualitative\_validation}, \textit{Carbon\_time}\}.$

$\mathbf{S}_{\text{DM}} = \{\textit{bounded\_rationality}, \textit{“Just-in-Time”}, \textit{uncertainty}, \textit{anthropocentrism}\}.$

$\mathbf{S}_{\text{maieutics}} = \{\textit{heutagogy}, \textit{dialog}, \textit{captology}, \textit{ethical\_behaviour}\}.$

$\mathbf{S}_{\text{agents}} = \{\textit{multimodality}, \textit{intentionality}, \textit{nonverbal\_communication}, \textit{Silicon\_time}\}.$

When some design-space dimensions are multifaceted and comprehensive (e.g., anthropocentrism) the granularity problem is avoided redefining the *dimension* as *subspace* and its *aspects* as *dimensions*.

### 8.2.3. Role and Scope of First Prototype

The *overt* role is to highlight the innovative architectonic of service-oriented decision making. Thus, the practical worth of the mechanism – even within a toy problem – was anticipated in 6.3.4. Indeed, in an intensive care unit humans and equipment are compelled to switch control to each other because humans need rest whereas equipment is not subject to Hippocratic Oath.

Figure 8.1 outlines the scope of the first prototype presenting three segments corresponding to a situation where care action urgency is comprised of three urgency levels as regards decision making: Level 1 (third segment: high fever, urgent), Level 2 (second segment: moderate fever, semi-urgent), and Level 3 (first segment: no fever, no urgency).

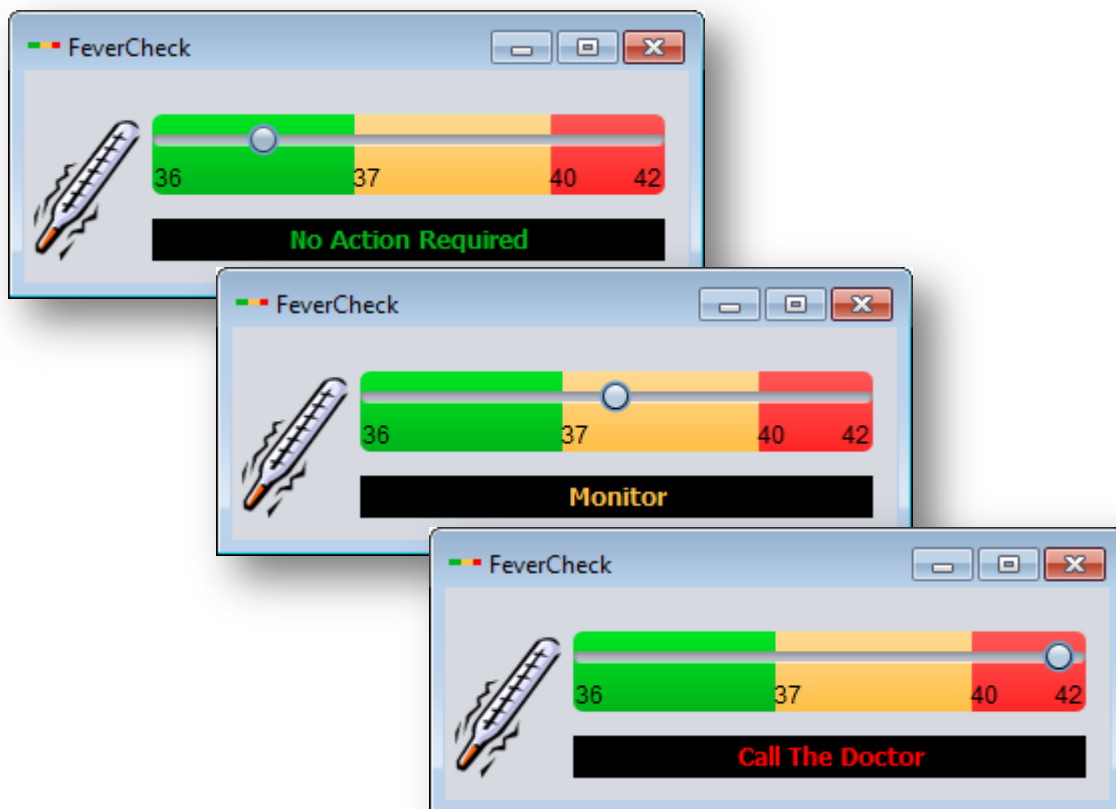
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<sup>9</sup>The strategy rendered in [26] is to found e-teaching for continuing education on e-maieutics.

Though, paradoxically, the input bar in Figure 8.1 is totally useless, since in both kinds of control decisions are made without any thermogram: if action is urgent, the bell is ringed “automatically” by the equipment or the physician is called “manually” by the mother. Moreover, even for a real-world situation the application needs an interface mostly when humans take control of the situation and must have updated information to make their decisions (thus the bar is rather a primeval DSS than an actual input bar).

The prototype has a much more important *hidden* role too: to reconcile this thesis with stances familiar within the prevalent paradigms, sending some messages to researchers and developers in the areas of both control engineering and DSS:

- a) There are mechanisms devised from an explicit (post-industrial) paradigmatic perspective (here service-oriented nondeterministic decision making) applicable in real-world problems independent of any paradigm. Indeed, the first version of this bar was proposed in the mid-nineties as universal input bar for all kind of uncertain data [92].



**Figure 8.1.** The three linear segments of the (pseudo)linear input bar.

- b) Corollary: as shown in 8.2.4 they can be implemented using conventional algorithmic software engineering.

- c) Not even the fundamental difference between “Caesium time” and “Carbon time” (6.3.4, 7.3.4.2) is perceptible for the end users: the first is concealed in the automatic system (“technology” has no time) while the second is the only time that counts.

- d) Corollary: asynchronous events are not perceived as such (e.g., running to the intensive-care room after an emergency call is not seen as exception handling); even synchronisation is implicit, hence unnoticed (no physician entering the room each morning at 8 a.m. sharp, does realise swapping from “automatic” to “manual” decision making).

#### 8.2.4. Implementing the (Pseudo)Linear-Bar Instance

Carrying out the implementation of the linear input-bar instance revealed itself as simple and straightforward as expected, mainly as regards technology, resources and components involved. Thus, common conventional object-oriented programming sufficed:

- *Technology*. The option was to use *Eclipse* as development environment and *Java* as programming languages because: a) their well-known and widespread nature; b) common UI components available sufficed for the linear instance, i.e., C/C++ or other lower level approaches could be disregarded; c) further instances of bars can be built based on generic architecture.

- *Components and resources*. In essence the implementation is a composition of standard elements from *Swing* (the Java primary GUI widget toolkit), combined and customized: *JSlider* for the input bar graphics and functionality, *JLabel* for displaying text and graphics, and *JFrame* as main application container.

Since the newness of the bar is rooted in its architecture, the only (somehow) relevant code samples here (Figure 8.2) are related to the segments and the actions to be taken.

```
JSlider source = (JSlider)e.getSource();
if (!source.getValueIsAdjusting()) {
    int knob_position = (int)source.getValue();
    if ((knob_position > p1) && (knob_position <= p2))
        doNoAction();
    if ((knob_position > p2) && (knob_position <= p3))
        doMonitorAction();
    if ((knob_position > p3) && (knob_position <= p4))
        doCallDoctorAction();
}
```

**Figure 8.2.** Code sample for the (pseudo)linear input bar.

The three zones (bar fragments) for “fever check”, are interpreted as follows:

- Healthy* – temperatures between 36°C and 37°C, marked by green background;
- Slightly sick* – temperatures between 37°C and 40°C, orange colour;
- Dangerously sick* – temperatures between 40°C and 42°C, red colour.

The input consists in dragging the “knob” on the slider to a proper position in a zone, triggering (or not) an immediate action:

- NO ACTION – if healthy; no action is required
- MONITOR, REPEAT – if doubtful, apply periodical rechecks;
- “CALL THE DOCTOR” ACTION – if very sick, hesitation can be harmful.



## 8.3. APPLYING THE DECISION-MAKING FRAMEWORK TO SERVICE PROVIDING

To be able to validate as mechanism *in embryo* the framework designed in 6.3, a toy sub-problem of the experimental model is defined in 8.3.1. On its basis, are outlined the mechanism essence (8.3.2), features (8.3.3) and innovative aim (8.3.4).

### 8.3.1. Defining a Toy Problem: Outlining Service-Requirements

Besides being integrable in the visual pattern recognition problem defined in 8.4, the toy problem must be relevant not just for showing the mechanism as “ADVANCED” but also for this thesis as a whole including its real application domain: continuing education. Thus, according to the objectives (2.2.1) it should be a significant part of a “nontrivial service to be provided (from a holistic perspective, within a user-centred application) by an agent-oriented interface in uncertain and changing environments” that allows “exploring e-teaching as boundedly rational system”. Considering that in [26] teaching is based on e-maieutics an appropriate problem is the dialogue-based first part of service providing: *outlining service-requirements*. Likewise, because the benchmark is a program transmitting the picture of Lena (3.5.2), the toy problem is based on various situations when different people could be interested in components of the picture getting processed.

On the other hand, this section is also a partial validation test, not only for the mechanism but also for the fifth objective (2.2.1), as explained in 8.3.4: the script for a dialog expressing service context and requirements, based on a genuinely anthropocentric mechanism must be understandable to a boundedly rational service beneficiary – even if the immediate script user is the application developer. Thus, the dialog between the toy service *beneficiary* (here “Lena’s mother” wanting to know whether her daughter still wears the hat she gave her), and the service *provider* (here the “entity” responding to the phone call: answering machine, interface agent or human) is outlined as follows:

### 8.3.2. Mechanism Essence: Anthropocentric and Decision-Oriented

Here essence means: a) any service-oriented development mechanism *must facilitate* intense HCI (human-computer interaction<sup>10</sup>): the application itself becomes an almost unremarked extension of the interface; b) to be helpful to service-oriented decision making the mechanism *must facilitate* tackling incomplete information. (Moreover, for this thesis “essence” means also organic integration with BR and JIT.)

From an explicitly implementation stance, for this framework it means:

- *Anthropocentric*. a) All functionality is *available only* through the interface. b) All functionality is *easy accessible* (user-friendliness is paramount for fighting both chaoplexity facets: *reducing cognitive* complexity and *hiding structural* complexity). c) Both essential features of HWI (human-world interaction, not human-computer interaction) must prevail:

---

<sup>10</sup> The term is used here because “computer” is compatible with both model *architecture* (agent-oriented interface) and *structure* (interface agent simulated by the very end user).

interfacing is *analog* and *multimodal*. d) Likewise, both essential features of cognition: *holism* and *nondeterminism*.

- *Decision oriented*. e) High level decision is *still* (sic!) a distinctly human attribute; thus, any DSS must be service-oriented to justify its “Support” attribute. Accordingly, the three following features are a *must*, i.e., any mechanism should illustrate them. f) When the real-world situation *allows* it, some decisions/actions can be entrusted to automata (including robots); on the other hand, when the real-world situation *requires* it, some decisions/actions must be assisted by non-algorithmic software (including bodiless agents). g) To achieve decision-maker acceptance, Carbon time is *sine qua non*. h) In chaoplex situations swapping between automatic and human control must be carried out “Just-in-Time” (Figures 5.1, 9.1).

If the first seven features are not convincingly shown in 8.3.3 and the last one in 8.3.4, the mechanism is useless and the experimental model fails – at least for decision making.

### 8.3.3. Mechanism Features: Verbal, Abductive, Non-Chrysippean

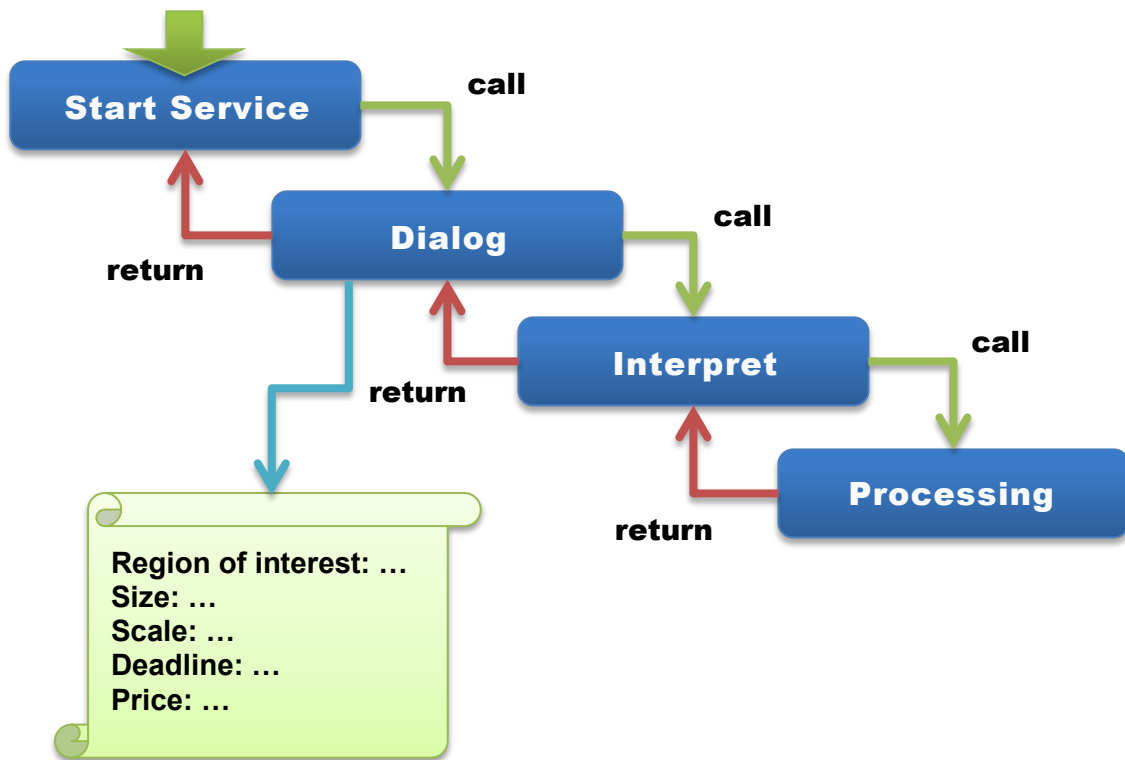
To impair redundancy with both the mechanism outline in 6.3 and its integration into the experimental model in 8.4, the seven features are demonstrated by Figures 8.4 – 8.11.

- *Verbal-oriented*. Despite trying in 8.4.2 to model also non-*verbal* communication, the mechanism *per se* is unable to prove convincingly more than non-*textual* communication. On the other hand, it was illustrated by the previous mechanism (described in 6.2. implemented in 8.2.3), as shown in Figure 8.1, where all input is both *analog* and *word-based*. Hence, the first two features are proved as well as the first component of the third one (*multimodality* is illustrated only in 8.4.2).

Though, the toy sub-problem is cardinal for validating the fourth feature too, through “*return value*” as shown in 6.3.1: a) *Holism* is present because the end user<sup>11</sup> is enabled to assess the (im)possibility of providing the *whole* service after carrying out only the *first part* – even more, just a *dialog*! b) *Nondeterminism* is present by the very *process* nature of any service, as expressed in Figure 8.3 through the meaning – and *practical consequence* – of “*return*” to the caller, here the user through the interface (normally via an interface agent, but sometimes directly, i.e., simulating the agent as in 8.4).

---

<sup>11</sup> While in 8.4 the “application end user” is the overall service beneficiary, for this sub-problem the “application-component end user” is the programmer – better said the application developer – because he/she is informed through “return” about the dialog outcome to be able to make the decision how to proceed (as *programmer*) or whether to proceed or not with the application (as *service provider*).



**Figure 8.3.** Embedded calls expressing the *process* nature of services.

- *Abduction-oriented.* Regarding Figure 8.9 it seems clear that the practical worth of this feature for service providing is limited because of the intrinsic weaknesses of abductive reasoning: in diagnosis the *cause* (of many possible causes) cannot be inferred apodictically from the evidence regarding the *effect* (6.3.3.3). However, clustering the unlikely causes under the cognitive umbrella of “*otherwise/default*” helps reducing uncertainty in decision making to the future contingents. Thus, “*otherwise/default*” – mandatory for getting rid of the binary straitjacket – is useful also for supporting decision making with incomplete information: the robot is instructed what action to perform, the human decision maker is “less uninformed”.

- *Non-Chrysippean logic concepts expressed in popular programming languages.* On the other hand, Figure 8.9 appears to illustrate a major instance of BR applied in CSIT: multifunctionality is implemented extremely simple by eliminating “*IF*” in high-level modules. Indeed, there are only multiple choice instructions in Figure 8.9, because any nontrivial service must have a variety of non-hierarchical options.

On the contrary, as regards the trivalent “*IF*” (6.3.2) – vital for procrastinating decisions involving future contingents – this thesis has no contribution except integrating it into the mechanism and for the first time into an experimental model.

In short the mechanism applies BR to convey “service-oriented semantics” via straightforward binary syntax, using only existing instructions as “*RETURN*” or “*SWITCH*”.

#### 8.3.4. Mechanism Innovative Aim: Engineering Device for ‘Balanced Decision’

This section should be read in two keys: a) an *extension* of 8.3.2 and 8.3.3 (the advisor’s stance) and b) an *introduction* to 9.3.3 (the PhD student stance, decisive for this thesis). Both stances rely on two batteries of facts – regarding *balanced automation* and *expert system brittleness* – and both acknowledge the *problem*: high level control was never satisfactorily supported by CSIT, neither for large scale systems (where full automation eventually failed), nor for strategic decision making (where algorithmic software failed to satisfy soon after starting, as both expert systems and DSS begun to show in the early nineties).

The conjecture that follows is mentally acceptable but cannot be defended in this thesis because the author lacks engineering background, real-time programming skills using powerful IDE (e.g., as offered by PDP minicomputers when automation was king), and process-oriented application development experience.

“The focus of BASYS is to discuss how human actors, emergent technologies and even organizations are integrated in order to redefine the way in which the value-creation process must be conceived and realized. [...] BASYS 2010 expects to discuss new approaches in automation where synergies between people, systems and organizations needs to be fully exploited in order to create high added-value products and services” [4]. This quote proves that the topic of “Balanced automation” is focused on in a way very similar to its initial approach in the mid-nineties. (The topic is commented upon in [118] where Camarinha-Matos, Terano, Martin, and Johannsen are quoted related to *integrated systems engineering*, *fuzzy engineering*, *appropriate automation*, and similar relevant terms.)

As regards expert system brittleness the problem was comprehensively dealt with in [93] where it is seen as the main *raison d’être* of agents (mainly in Section 4.1.4. titled “Criticising Conventional Approaches, from the Application Standpoint”).

As a result, it may be inferred (from the above) that “Computer-Aided *x*” almost failed for  $x = \textit{decision making}$  and (from the entire thesis) that it failed for  $x = \textit{IT application development}$ . On the other hand, automation had three huge plus points comparing it to DSS: a) the lasting and tremendous effectiveness of Moore’s Law in both hardware and software; b) the adequacy of algorithmic software; c) the old tradition of humans controlling technology “offline”. Though, expert systems are practically dead and BASYS conferences are very alive. Hence, the problem is unsolved almost two decades after emerging.

It may be conjectured that the cause is related to the implication chain below starting with the working assumption that DSS failed because they lacked credibility:

Credibility → “open to inspection” → “able to be inspected” → human-oriented interaction → reduced cognitive complexity → boundedly rational interface → non-algorithmic software → anthropocentric design → suitable mechanisms (for instance, *ED*).

Why “*ED*”? “Engineering” is self-explaining. “Device” suggests that it is neither predominantly algorithmic (based on circular time), nor purely non-algorithmic (based on human-

like agent time) because its main objective is to swap online control between “automatic” and “manual”.

## 8.4. MERGING THE MECHANISMS IN VISUAL PATTERN RECOGNITION PROBLEMS

More than expected, the practical effects of Moore’s Law – here regarding broad-band technology – shaped the evolution of the experimental model both negatively (no problem, no research, no benchmark, 2.3.4) and positively: the *toy problem* defined in 8.3.1 was significantly *extended and adapted, regardless of benchmarks* (8.4.1). Thus, the *general architectonic framework* (8.4.2) embraces all innovative features of the mechanisms defined in 6.2, 6.3 and applied in 8.2, 8.3. Those features are illustrated by *code samples of “semiotic-oriented software engineering”* (8.4.3). Finally, the experimental model is validated (8.4.4) according to 8.1.2.

### 8.4.1. Extending and Adapting the Toy Problem Regardless of Benchmarks

The side effect of Moore’s Law abridged by the briskly phrase above (“no problem, no research, no benchmark”) needs clearing up: within incremental research – including image processing – successive optimization algorithms improved “State of the Art” results in two years with a few percent whereas broad-band technology doubled the results with (almost) no research effort. Thus, benchmarks – no matter how popular, Lena included – tend to become irrelevant, at least for research aims.

Paradoxically, technological progress added a third vulnerability<sup>12</sup> to the experimental model. However, it was rather easy to surmount it due to the unexpected evolution as regards the conceptual shift from Aristotle towards Lao Tzu allowing to conceive (5.4.3), set up requirements for (6.1.2), develop (6.3), and implement (8.3) mechanism features enabling an embryonic “Semiotic-Oriented Software Engineering” (SOSE2, the quotes suggest that much more transdisciplinary research is needed before daring to assert the birth of a new branch of software engineering – in fact SOSE1 should be already accepted as sub-branch of AOSE). As a result, the toy-problem narrative was reformulated to involve an interface displaying enhanced functionality (mainly supporting decision making) that allows demonstrating all new features *in actu*. Relating to an experimental model – not to the core of a commercial application – the architectonic framework (8.4.2) is “general” as abstraction level not as scope (common features of service-providing applications are included in the model but are not focused on).

As regards horizontal extending, there are some minor technical enhancements including code sharing among all cases. This code is now implemented to serve the simplest case (labelled “mother” and described in Figures 8.4 - 8.10) and the most demanding

---

<sup>12</sup> The first two were: a) avoiding continuing education as target application domain; b) simulating the interface agent. Both have been overcome as shown in 2.3.4, 3.5.1, 8.3.1 and 1.3.2, 2.3.2, 2.4, 6.1.4 respectively.

case, labelled “detective” since it describes a forensic service requiring more zone of interests, better resolution, more chrominance information, etc.

### 8.4.2. General Architectonic Framework

There are several echelons or stages in quitting the Western tradition when developing decision-oriented software (epitomised in this thesis by Aristotle as philosophy and by Chrysippus as logic) and embracing the Eastern approach to logic in tackling real-world situations (epitomised by Lao Tzu and promoted vigorously by Zadeh). In part they can be regarded also as abstraction levels and as requirements for agent-oriented mechanisms (6.1.2) and are illustrated here as architectonic features of the experimental model:

- *Avoiding numbers.* The region of interest is delineated – and transmitted as actual parameter – without any geometric reference to the position on the image (Figure 8.6).

- *Using natural language.* The region is outlined and stored using words (Lena’s mother pronounced the word “hat”, she did not expressed the word in any kind of digital translation). Thus, the three images in Figure 8.5.a mean: take from image A the region B (interpreting the word “hat”) and process it (Figure 8.10) to yield image C as required during the dialog (here just doubling the size).

- *Fighting graphocentrism.* In the second prototype (not yet convincingly implemented because of simulating the interface agent) the concept “hat” is not expressed textually but through mouse movements that have nothing to do with the character string “hat”.

- *Fighting logocentrism.* In a later prototype the client could avoid uttering “hat” either via mouse movements as above or indicating the region of interest through body language.

Perhaps even more important – albeit less noticed than the shift from numbers to other symbols – is reducing the weight of *dichotomous* concepts as shown in 6.2.2, 6.3.2, 6.3.3, 8.3.3. This trend is reflected in two manners of getting rid of the semantic principle of bivalence: whenever possible offering a large range of alternatives (Figure 8.9) and – when the context requires or allows the simplification of “*tertium non datur*” – choosing only the most likely variant and treating the other as explicit or implicit exception (Figure 8.7).

### 8.4.3. Technology: Code Samples of “Semiotic-Oriented Software Engineering”

Referring the unbiased concept “technology” in the title is the result of compromise between (huge) frustration about *object-oriented IDEs as major hindrance of CSIT research* (8.4.3.1) and (modest) expectations about the effectiveness of *illustrating new software engineering by outworn tools* (8.4.3.2).

#### 8.4.3.1. Object-Oriented IDEs as Major Hindrance of CSIT Research

If the awkwardness of embedded “IFs” in Figure 8.9.b is easily avoided by the “SWITCH” in Figure 8.9.a, it is hard to keep the cognitive separation of *architecture* and *structure* – vital for any engineering endeavour – when calling a (service-oriented) subprogram is expressed conventionally as in Figure 8.4.b.

```

int returnValue, processingResult;
// call the processing module: execute_processing(...)
processingResult = execute_processing(originalImage,partialImage,resultImage,
                                   scaleValue);

returnValue = processingResult;
return returnValue;
// the return value propagated to caller(fig. 8.3)

```

a)

```

// call the processing module: execute_processing(...)
execute_processing(g_mem,originalImage,partialImage,g_mem.resultImage,
                  scaleValue,g_mem.retValProcessing);
g_mem.retValInterpret=g_mem.retValProcessing;
// the return value of service providing propagates dynamically from
// callee to caller(fig. 8.3)

```

b)

**Figure 8.4.** Calling a subprogram: a) commonsensical; b) conventional Java variant.

Unfortunately, the commonsensical variant in Figure 8.4.a is impaired by several semantic and syntactic difficulties:

- The ordinary sins of a language family stemming from an efficient (twenty years ago) but tiresome (always) macroassembler are lasting, despite minor cosmetic improvements. For instance, a procedure-like subprogram is seen as a “void function” instead of keeping the normal idea of functions as subclass of procedures. Moreover, global variables have to be carried literally in an object from a module to another (Figure 8.11).

- Elementary programming techniques, necessary for rational application development (including structured or modular programming) are inapplicable without clumsy outmanoeuvring irrational shortcuts as shown in Figure 8.4. As a result even potential advantages of combining related IDEs are lost: thus, the *JavaScript* dialog suggested in Figure 8.8 had to be written in *Java* to allow acceptable integration in the experimental model.

- The drawbacks above are aggravated when developing service-oriented applications even somewhat more complex than a website. Referring again to Figure 8.8, the benefit of using an interpreter-based language for an obviously non-algorithmic dialog was lost too. This is acutely disagreeable when other software tools to model nondeterministic real-world situations, like multithreading or exception handling, are practically unusable in object-oriented IDEs – if available altogether.

The consequences are far-reaching (8.4.4, 9.3.2, 9.3.3).

#### **8.4.3.2. Illustrating Semiotic-Oriented Software Engineering by Outworn Tools**

In fact this Illustration is the role of the code samples but 8.4.3.1 was necessary to avoid distracting attention from the innovative features, hidden by ungainly outflanking. Now the samples can be focused on as the *structural* mirroring of the *architectonic* framework (8.4.2).

All three images in the code of “Interpret” (Figure 8.6 and Figure 8.4) are handled by words in plain English expressing pointers: `originalImage` is a constant, `partialImage` an input parameter, and `g_mem.resultImage` an output parameter. They point to the three images in Figure 8.5.

Here is illustrated more than the simple way of getting rid of bivalence by offering more than two alternatives: for post-industrial decision making in uncertain and highly dynamic environments “standardising” the “*DEFAULT*” in “*SWITCH*” enables all decision-oriented features (6.2.2, 6.3.2, 6.3.3, 8.3.3) – above all the vital guarantee that always *something* is done (either an automatic action is performed or an emergency message is conveyed).

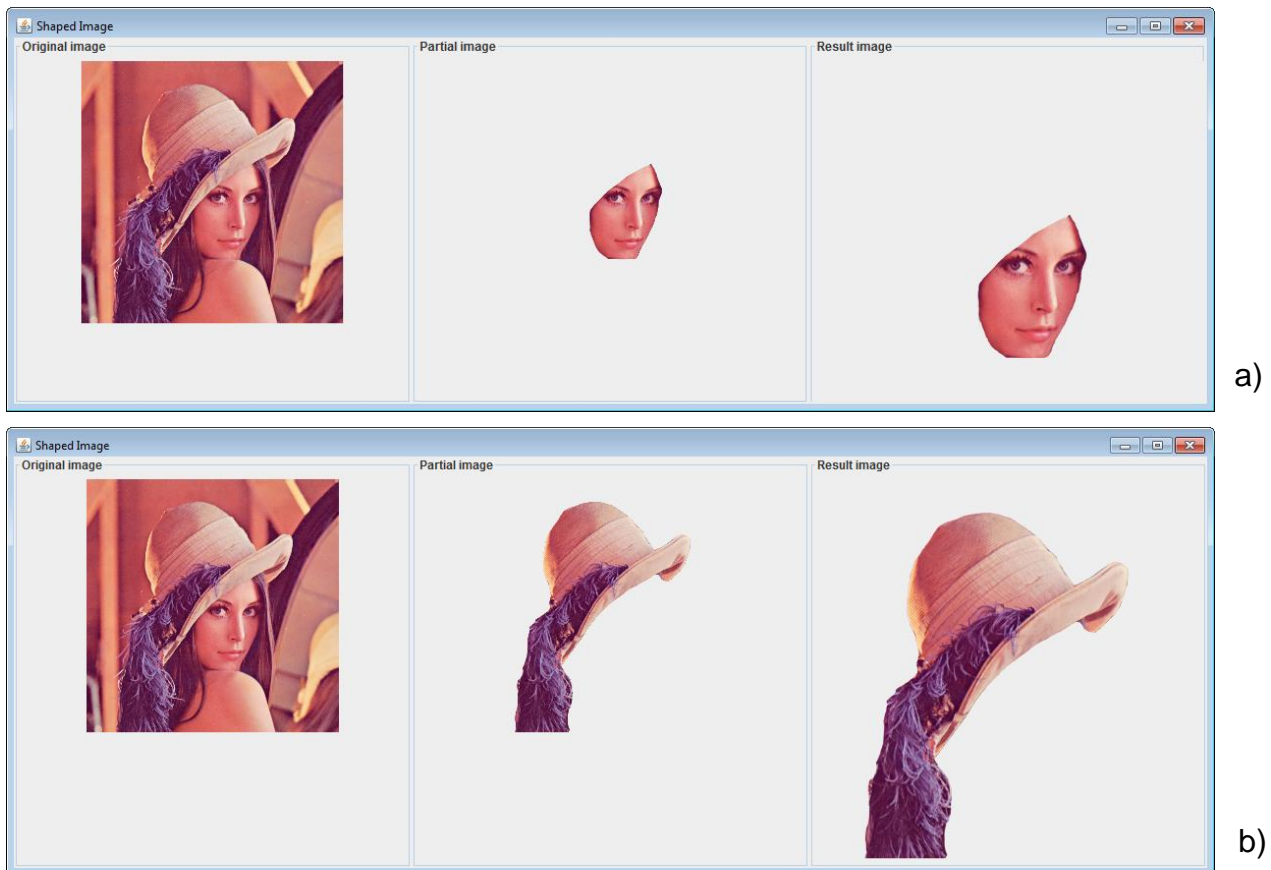
Besides avoiding “*IFs*”, even when bivalence is accepted as simplification the code shows how a cardinal leitmotif of this thesis, the cameleonic “return” (6.3.1, 6.3.3, 6.3.4, 7.2.3, 7.3.4.2, 8.1.3, 8.1.4, 8.3.3, 8.4.2, 8.4.3.1, 8.4.4, 9.3.2, 9.3.3) is easily implemented using variable return values.

#### **8.4.4. Validating the experimental model, in spite of “hostage syndrome”**

Probably this is the first purely qualitative validation of an engineering model in Romania. Certainly it is the first such validation for an experimental model of a CSIT PhD thesis. On the other hand, it is obvious (albeit not explicitly acknowledged) that: a) conferring a PhD is based on an intrinsically qualitative validation; b) the quality of researcher (PhD student) and the quality of research (thesis) are hard to be evaluated separately; c) even more so in engineering; d) even more so in CSIT. As a result the model validation should follow the guidelines for service validation (8.1) applied within an “engineering-compatible” framework (9.1.1, because it must encompass the whole thesis). Thus, a vicious circle is inexorable: the same PhD commission evaluates thesis and experimental model, being subject to CSIT hostage syndrome. To reduce the favourable empathy involved, the model must be evaluated related strictly to its output: how does it mirror (sic!) the features it is aimed at. This task is easy to fulfil, due to the second mechanism – devised in 6.3 and applied in 8.3 – regarded here as *ad hoc* decomposable in its design space features (8.3.2 – 8.3.4). Consequently, the experimental model is validated pairing features with figures (either yielded by running the model or implementation code samples):



- Anthropocentric.



**Figure 8.5.** Image-based validation: original, region of interest, processed region.  
a) Region of interest: "face"; b) Region of interest: "hat".

```
public void interpret(GlobalMemory g_mem, String[] requestset) {
    // this function is called by "dialog", interprets the requirements
    // specifications and calls "execute_processing"

    g_mem.retValInterpret = GlobalMemory.SERVICE_FAILED;
    // preparing the next prototype

    String roiName = requestset[0];
    double scaleValue = Integer.parseInt(requestset[1]);
    // interpreting the requirements from requestset
    BufferedImage partialImage = (BufferedImage) g_mem.parts.get(roiName);
    BufferedImage originalImage = g_mem.originalImage;
    // preparing arguments for calling processing

    // call the processing module: execute_processing(...)
    execute_processing(g_mem, originalImage, partialImage,
        g_mem.resultImage, scaleValue, g_mem.retValProcessing);
    g_mem.retValInterpret = g_mem.retValProcessing;
    // the return value of service providing is propagates dynamically
    // from callee to caller(fig. 8.3)

    return;
    // control is returned to dialog
}
```

**Figure 8.6.** Avoiding numbers as much as possible: Code of "Interpret".

- **D**ecision-Oriented.

```
Start Service

returnValue = SERVICE_SUCCEEDED
.
. // trying to provide service
.
. // "if" (see comments below) the service is not provided:
returnValue = SERVICE_FAILED
. // trying to fix it
.
. // "if" (see comments below) fixing successful:
returnValue = SERVICE_SUCCEEDED

Return returnValue
```

**Figure 8.7.** Pseudo “Exception handling”: meaningful “RETURN” still without “IFs”

- **V**erbal.

```
public void dialog(GlobalMemory g_mem) {
    // for the time being it remains as a function called by WinMain;
    // here WinMain is missing because it is outside the dialog itself

    g_mem.retValDialog = GlobalMemory.SERVICE_SUCCEEDED;
    // preparing the next prototype

    String roiString;
    String scaleString;

    roiString = JOptionPane.showInputDialog("Region of interest:");
    // since this is a DLL module it does not use "return" inline with
    // 6.3.1, hence no service result can be verified
    scaleString = JOptionPane.showInputDialog("Scale factor:");
    // idem

    String requestset[] = { roiString, scaleString };
    // the vector is used to have a common structure for both "mother"
    // and "detective" case

    interpret(g_mem, requestset);
    // call "interpret"
    g_mem.retValDialog = g_mem.retValInterpret;
    // the return value of service providing is propagates dynamically
    // from callee to caller(fig. 8.3)
    return;
    // because of using DLL modules "return" is here confusing and
    // useless
}
```

**Figure 8.8.** Script, or pseudocode, or narrative of a post-industrial dialog?

- **A**bductive, **N**on-**C**hrisippean.

<pre>switch (client){   case MOTHER:{     // call "mother" dialog     break;   }   case SECOND:{     // call "second" dialog     break;   }   .   .   .   case DETECTIVE:{     // call "detective" dialog     break;   }   default:{     doSomethingIfOtherwise();     // warning no client today   } }</pre>	<p>a)</p>	<pre>if (client == MOTHER){   // call "mother" dialog } else   if (client == SECOND){     // call "second" dialog     .     .     .   }   else     if (client == DETECTIVE){       // call "detective" dialog     }     else {       doSomethingIfOtherwise();       // warning no client today     } }</pre>	<p>b)</p>
---	-----------	---	-----------

**Figure 8.9.** From Aristotle towards Lao Tzu, even in *Java*, avoiding “IFs”  
a) Using “SWITCH” to easily avoided “IFs”, b) embedded “IFs”.

- **E**ngineering.

```
public void execute_processing(GlobalMemory g_mem, BufferedImage imga,
    BufferedImage imgb, BufferedImage imgc, double scaleFactor) {

  // preparing the next prototype
  g_mem.retValProcessing = GlobalMemory.SERVICE_SUCCEEDED;

  // apply a scale operation on the region of interest
  AffineTransform at = new AffineTransform();
  at.setToScale(scaleFactor, scaleFactor);
  AffineTransformOp op = new AffineTransformOp(at,
    AffineTransformOp.TYPE_BICUBIC);
  imgc = op.filter(imgb, null);

  // shows the images with all requirements applied
  displayImages (imga, imgb, imgc);

  return;
  // control is returned to "interpret"
}
```

**Figure 8.10.** Yielding the required image. Code of “Processing”.

- Device.

```
public class GlobalMemory {
    final static int MOTHER = 1;           // simplest case
    final static int SECOND = 2;          // dummy case/stub
    final static int THIRD = 3;           // dummy case/stub
    final static int FOURTH = 4;          // dummy case/stub
    final static int DETECTIVE = 5;       // most complex case
    final static int SERVICE_FAILED = -1;  // failed service
    final static int SERVICE_SUCCEEDED = 1; // successful service

    int clientType;

    BufferedImage originalImage; // handle original image
    BufferedImage resultImage;   // handle result image

    Shape ROI_shape;            // shape designating the region of interest
    double scaleValue;          // required by affine transformation
    // for possible extensions to other kind of situation where
    // also diminishing could be considered;

    HashMap<String, Object> parts = new HashMap<String, Object>();
    // partition of the original image, e.g. hat and face respectively,
    // see figure 8.5.

    int retValInterpret;        // return value of interpret
    int retValProcessing;        // return value of processing
    int retValDialog;           // return value of dialog
}
```

Figure 8.11. Carrying global memory throughout the application.

## NINTH CHAPTER

### Evaluating: The Good, the Bad, and the Future Contingent

*Mir selber ist, was mir gelang, gar spät gelungen,  
Doch mehr nun freut mich, dass ich rang als was errungen*  
FRIEDRICH RÜCKERT "Weisheit des Brahmanen"

The evaluation is made against three frames of reference: the **thesis** (*accomplishing the objectives*, 9.1), the **author** (self-evaluation: *summarising the original contributions*, 9.2), and the **field** (*open problems*, 9.3). However, to ease evaluation from other scientific perspectives too, the thesis ends with a summary of its contributions rewritten in line with *established frameworks* (9.4).

#### 9.1. ACCOMPLISHING THE THESIS OBJECTIVES

After setting up an *evaluation framework* (9.1.1), the thesis *achievements and failures* are assessed against it (9.1.2). Taking the research context into account, the *expectations for EU2020 theses* are also contemplated (9.1.3).

##### 9.1.1. Evaluation Framework

Evaluating the thesis without a clear framework could be subject to irrelevance because:

- a) Exploratory research in CSITAO involving paradigm shifts increases the risk of biased evaluation, no matter the paradigm defended.
- b) "Engineering-compatibility" and qualitative validation are yet hard to merge.
- c) Requiring the experimental model to be defended in the third (penultimate) technical report was a mixed blessing: it allowed to have a "Plan B" (four objectives) but diluted "Plan A" (the very wording of the most daring fifth objective involved postponing and downgrading its evaluation until the experimental model was assessed).
- d) Failing to attract researchers in humanities (psychologists, sociologists, educational scientists, linguists, etc.) in an inherently transdisciplinary research despite two papers published by Elsevier [62], [61] brings in an even more one sided evaluation.

To avoid augmenting the bias (in this stage evaluation is – inevitably – predominantly a self-evaluation) all assessments below are steered by the following changes occurred after asserting the objectives in 2009 (in parentheses are shown the reasons among those stated above for setting up the framework):

- a) Defending non-algorithmic software for decision support and acknowledging in the same time the *sine qua non* role of algorithmic software in control engineering yielded an unfinished – hence exposed – research about the deep differences between various temporal dimensions (a).

b) Most explanations regarding the experimental model are based on code sample written in the user-unfriendly Java language – because neither Ada# nor Python satisfied software engineering expectations “Just-in-Time” (a, b) (9.3).

c) The fifth objective was added to with “*and substantiating first results in embryony SOSE development rules implementable using common IDEs*” (c, b). Likewise, all later sub-objectives were merged into coherent objectives (c, d, b).

d) Lacking transdisciplinary support, the thesis had to become more self-reliant shifting in part the target (as application domain aimed at) from continuing education towards decision making (d, b).

### 9.1.2. Achievements and Failures

To avoid ambiguities all evaluations refer to objectives but *evidences* state explicitly in parentheses the subchapters, or (sub)sections containing the proof that a specific (sub)objective or component was met (if necessary, some comments are added). For the sake of readability, the objectives (2.2.1) are restated or repeated below.

**OBJECTIVE 1. *Revisiting thoroughly the concept of bounded rationality, in view of its roles in a post-industrial (service-based) society. Choosing a Lingua Franca for holistic approaches able to promote transdisciplinarity (mainly as regards psychologists). Expressing bounded rationality in terms of this language.***

The concept of *bounded rationality*, was not just systematically revisited – from psychologic feature to subconscious approach (4.1) and from conscious hindrance to legitimate excuse for incoherent decision-making (4.2) but was redefined as polysemantic. Acknowledged as cognitive mechanism favouring simplicity (4.1) and illustrated as basic psychologic mechanism able to counteract cognitive complexity (4.3.1), BR was investigated related to decision making, behavioural economics, approximation, and uncertainty (4.2) setting up its main role in the post-industrial era: fighting cognitive chaoplexity (4.3).

Since the major new role of BR as “educational mechanism” was hard to confine in the classical conceptual framework, and for CSIT reasons far beyond this thesis – including holistic approaches in the post-industrial era (5.1.1), semantic web and general culture (5.1.2) – the Lingua Franca had to be a metascience and the only suitable found was GST (General System Theory) because it is able to express in a transdisciplinarily palatable jargon the vital relationship between cognition and cybernetic, automatic, or intentional systems (5.2).

On this groundwork BR was expressed in terms of GST, including the ambivalent key aspect of BR as feedback: a) long-term quasi-stability is preserved through BR acting as negative feedback (5.3.3); b) short interludes of creativity can be boosted through BR acting as positive feedback (5.3.4).

**OBJECTIVE 2. *On this basis, substantiating the ambivalence of bounded rationality (cognitive limitation and IT guiding principle) within the agent-orientation paradigm, in applications destined to perform in dynamic and uncertain environments). Therefore: a) Investigating preterminologic BR (mainly the anthropogenetic divergence between optimization and simplicity). b) Exploring the role of BR as***

**“psychological stabiliser” (through negative feedback). c) Extending the analyse to (largely preterminologic) synergy as (boundedly rational) resource amplifier.**

As archetypal application destined to open, dynamic, and uncertain environments was chosen the EU2020 thesis “Non-deterministic e-Teaching in Uncertain, Dynamic Environments. Experimental Model Based on Memetic Engineering” [26] where the AO paradigm is *sine qua non*. In the challenging environment of post-modern educational chaoplexity (7.1.1, 7.1.2). BR was substantiated as both *cognitive limitation* and *IT guiding principle* (7.1.3, 5.1.4).

Both history and psychology show that “simple” was always paramount, whereas “best” became arguable when mathematics became (too) complicated (4.1.1).

BR as “psychological stabiliser” was proved in three steps: choosing an interesting topic (7.3.1) or a pervasive habit (7.4.1); investigating *memetic stability* that assure their usability (7.3.2, 7.4.2); proposing a boundedly rational way to exploit simplicity in e-teaching via extrapolating similar topics (7.3.3) and behaviours (7.4.3).

To achieve inter-paradigmatic synergy, modelling requires innovative (i.e., nondeterministic, noncategorical, agent-oriented) software (5.4.4).

**OBJECTIVE 3. Instantiating this approach for continuing education, via a framework able to manage educational chaoplexity based on bounded rationality as common denominator of, mechanism for, and connection between the two facets of continuing education: e-teaching and e-learning.**

The framework able to manage educational chaoplexity based on BR as common denominator was carried out only for e-teaching since no research started yet as regards service-oriented e-learning. However, regarding EDCHY as the key problem of permanent education able to be settled via BR as educational strategy, based on a first attempt to include BR in e-teaching (7.1.3), it was shown that BR can tackle EDCHY and that it is able to alleviate the temporal problem intrinsic to permanent education (7.1.4).

Here comes in the first failure – or, at least, major vulnerability – of this thesis (2.4.3, 3.1.2, 9.1.1): failing to cooperate with social scientists, any models based on BR as basic “educational mechanism” aimed at tackling chaoplexity (4.3.1, 5.2.4, 5.3.3, 5.4.4, and practically the whole seventh chapter) is not *trans* but *pseudo-multidisciplinary*, entailing the unacceptable risk of diletantism. As a result, some vital aspects for [26] cannot be seen as conclusions, but have to be labelled as expectations (9.1.3).

**OBJECTIVE 4. Validating the approach by carrying out an experimental model of a nontrivial service to be provided (from a holistic perspective, within a user-centred application) by an agent-oriented interface in uncertain and changing environments. To ensure the qualitative validation soundness, the application field chosen is “Visual pattern recognition”.**

The model *architecture* (8.4.2) expressed all the requirements to fulfil the objectives, its *structure* (8.4.3) implemented all of them; thus *validation* was carried out (8.4.4) simply by pairing features with figures.

Here comes in the paramount inconvenience of this thesis: trying to demonstrate new paradigms through IDEs that are out-of-date even from an old paradigm perspective.

Although not a failure *per se* it proved to be an alarming hindrance. Thus, the problem is serious, affects any exploratory CSIT research and cannot be solved within the time-span of EU2020 theses; it is still open for the next future (9.3.2, 9.3.3).

**OBJECTIVE 5. *Exploring the paradigmatic shift towards building Computer Science rather on semiotics than on mathematics and substantiating first results in embryony SOSE development rules, implementable using common IDEs.***

Since the “first results” are (self)evaluated as being original and consequential, to impair redundancy they are summarised (9.2) as such.

### **9.1.3. Expectations for EU2020 theses**

At the moment when this thesis is finished there is just one active EU2020 thesis [26]; thus the expectations regard e-teaching models and have as time horizon November 2012:

- Bounded rationality, is much more than an excuse for poor decision making and becomes vital for continuing education because – as key psychological feature – it is *the most stable* dimension involved.

- To be sustainable in the long run any educational endeavour must be modelled based on BR. In continuing education, to overcome the temporal hiatus between teaching and learning, this educational strategy will become *a must*.

- As regards *teaching* it proves quite difficult to solve the “separation paradox” (2.1.2, 3.2.3, 3.4.1, 7.1.4, 7.2.2, 7.3.4) without an intense transdisciplinary endeavour, since it lacks credible performance metrics.

- Any metamodel of teaching should be based on psychosomatic features (first of all on BR) and can be validated so far through convincing – albeit circumstantial – evidence.

- Helplessness in managing situations too chaoplex for human BR can be lessened investigating the real world according to the huge potential of BR itself. (Unthinkable without psychologists playing the first violin.)

- Corollary: transdisciplinary teamwork is mandatory. Teams should be led by psychologists, not by computer scientists.

- Unfortunately, cognitive psychology – while consistent and established – seems rather inappropriate as corpus of knowledge because of a predominantly deterministic (left brain hemisphere, serial, “von Neumann-like”) approach.

- Since time is inexorably linked to the nature of (nontrivial) services, software should be based on *processes* not on *programs*, i.e., on nondeterministic software.



## 9.2. SUMMARISING THE ORIGINAL CONTRIBUTIONS

To *facilitate* their evaluation, original contributions are organised in decreasing order of importance: *conceptual pillars* (9.2.1), *apparatus* (9.2.2), *approaches* (9.3.3), and other innovative outcomes, *effects of serendipity* (9.2.4). Hence 9.2.4 will be presented even more abridged than 9.2.1 (just three examples). Why? Because a holistic boundedly rational approach is better than a reductionist one that forces the evaluator to be a “two pass compiler”, referring uncomfortably to sections above.

Likewise, to *enable* their evaluation, original contributions refer to open questions below (9.3) because the thesis lives or dies with its questions left open. In fact, they are the “new frontier” and evaluation means attesting that the frontier was pushed far enough. For this thesis it is even more telling than for other exploratory research because it has to be self-consistent: a PhD in CSITAO is itself an ongoing process, not a finished object. Thus, its legacy (*open* questions, mainly for EU2020 research [26]) prevails over *closed* (sic!) ones (four partially outdated technical reports merged into a thesis). To ease reading when referring open questions, “9.3” was considered “common factor”. (Likewise, since 9.3.2 is practically an extension of Q1 in 9.3.1, it is not explicitly referred to.)

### 9.2.1. Conceptual Pillars

The first two main conceptual pillars of this thesis existed *per se* long time ago (for instance BR in its preterminological era) but were remodelled separately and merged together into service-oriented decision making as follows:

***Bounded rationality.*** In line with the much extended first objective BR was:

a) *Redefined as polysemantic*, adding three new meanings to the syncretic connotation of “hindrance/excuse for poor decisions”: a1) lasting psychologic *feature*, critical for nontrivial decision making; a2) main (decisional) *mechanism* in service-oriented (online) decision support, based on incomplete information; a3) basic e-teaching *strategy* for continuing education tending to become a cardinal educational *guiding principle*.

b) *Expressed coherently* in GST. Systemic attributes as “*negative feedback*” or “*stability*”, vital for applying BR as mechanism, are mentally easy accessible (Q1, Q4, Q3) to social scientists (e.g., to express transdisciplinary research with BR as “cognitive engine”).

c) *Substantiated* as regards meanings a2) and partially a3) in experimental models (Q4, Q3, Q1, 3.e) validated *in ovo* (Q4, Q4C, Q1, 3.d). Thus, in the challenging environment of post-modern educational chaoplexity BR was ascertained as both *cognitive limitation* and *IT guiding principle* and was proved as “*psychological stabiliser*”. In short BR was applied in managing educational chaoplexity as *common denominator* of, *mechanism* for, and *connection* between the two facets of continuing education: *e-teaching* and *e-learning*.

“**Just-in-Time**”. The concept was:

a) *Upgraded* from the status of label for an essential inventory strategy (in the industrial era) to a *sine qua non* requirement for (nontrivial) service providing (in the post-industrial era) and more general (Q4, Q4C, 3.a, 3.e, 3.d) for any decision making.

b) *Semantically enriched*. As superseder of “*real time*” it becomes a *raison d’être* feature of any service and of any decision making (Q4, Q4C, 3.a, 3.b).

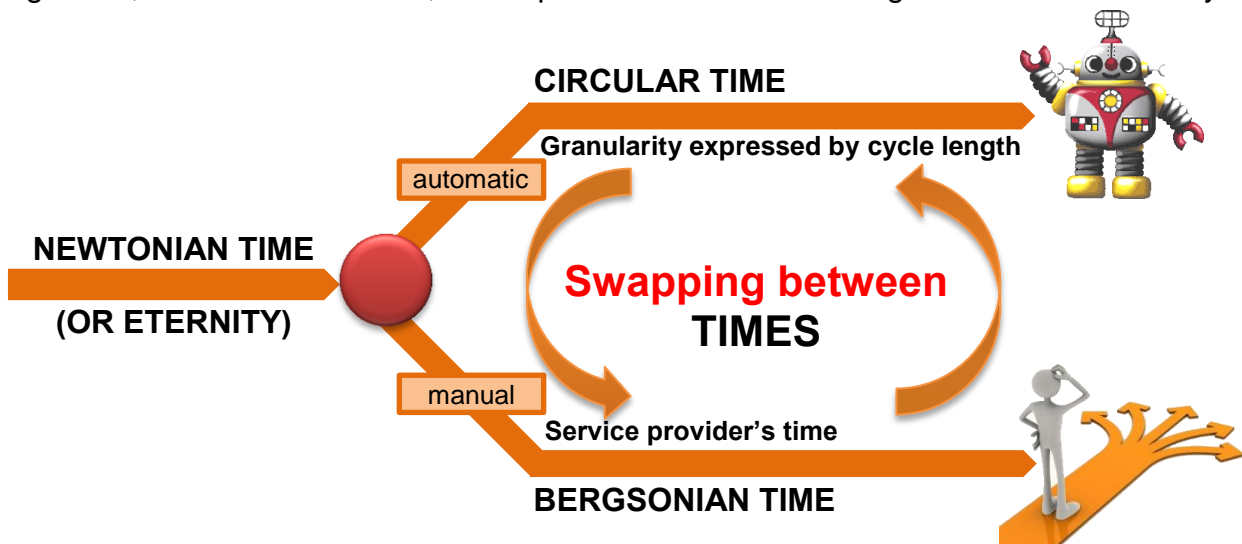
c) *Merged with bounded rationality*. As a result of the compound concept “BR + JIT” (Q4, Q4C, Q1), this thesis endorses previous claims [64] adding to Zadeh’s “*Rationale 2 for granulation: precision is costly*” [87]: “*Rationale 3: precision is unnatural*” (from a BR stance) and for decision making in chaoplex and risky situations, even “*Rationale 4: precision is harmful*” (from a JIT stance).

**Agent-Orientation**. It is the third conceptual thesis pillar but will be commented upon only below since no original contribution is to mention at the conceptual echelon.

### 9.2.2. Apparatus/Mechanisms

The term “apparatus” was chosen from the exploratory research perspective to suggest a cognitive *modus operandi* while “mechanisms” reflects the engineering science perspective. The order is of decreasing importance as “apparatus” (considering the validation process, it is also the order of increasing importance as software engineering “mechanisms”). Thus, here are mentioned a general *principle* for online decision support and two non-algorithmic mechanisms for word-based modelling:

- **Swapping between times (to make balanced decision)**. The importance of asserting and proving the time pattern in Figure 9.1 is highlighted by the fact that neither control engineers, nor mathematicians, nor IT professionals acknowledge the time dissimilarity.



**Figure 9.1.** What time is it? Swapping from time to time(s).

*Automatic control*: decisions are *algorithmic* and made by *robots*. Time is either noninteresting (algorithm *stops* when a problem is solved) or circular (“*return*” restarts a loop).

*Manual control*: decisions are *boundedly rational* and made by *humans*. Time is Newtonian in simple situations, and must be Bergsonian in chaoplex situations because services (decision support included) are for humans (“*return*” was semantically enriched, since “*return -1*” is mandatory for warning the user that the service failed).

In the industrial (*product-oriented*) era, the prevalent (algorithmic) paradigm was *sufficient*; in the post-industrial (*service-oriented*) era, both paradigms are *necessary*. Hence swapping between times is mandatory and decisions should be “balanced” (Q4C, Q4, 3.d).

- **ADVANCED**. The service-oriented decision-making framework was validated qualitatively for all the letters in the backronym. It goes beyond Zadehian “Computing with *words*” towards “Computing with *images*”, in its semiotic *spirit* and not within its mathematical *distortion*<sup>13</sup>.

- **Decision input bar**. The multifunctional bar for decision input is: a) devised from an explicit post-industrial perspective (service-oriented nondeterministic decision-making); b) universal (usable for all kind of uncertain input, and for all psychophysical laws governing cognition Q4, Q2); c) applicable to real-world problems independent of any paradigm (Q4); d) implementable using conventional algorithmic software engineering.

- **Illustrating SOSE with outworn IDEs** (in applications destined to perform in dynamic and uncertain environments). ADVANCED should work incorporated in an interface agent. This macro-architectonic feature (service-providing process, based on multimodal interfaces and aiming at decision making with incomplete information) required by the model was the only feature yet unaffordable with popular IDEs. All other innovative features could be validated qualitatively using plain *Java* (i.e., giving up the major advantages of using the dialog-oriented *Java Script*, to avoid the architectural drawbacks of a Web application). For instance, “non-Chrysippean practices” allowing flexible and varied service providing were expressed straightforwardly in *Java*, replacing “IF” by “SWITCH” and using “DEFAULT”.

### 9.2.3. Approaches

Perhaps excepting the last one, all approaches are customary. Hence, here only value added is abridged.

- **Anthropocentrism**. Emphasis was on: a) symbolic interfaces; b) fighting both chaoplexity facets: *reducing cognitive* complexity and *hiding structural* complexity; c) interfacing is *analog* and *multimodal*; d) autonomous behaviour from all its sources: living beings, automata, and software; e) shifting from quantity (testing the *technological efficiency* of the application) to quality (validating the *target-oriented effectiveness* of its actual use). (Q1)

---

<sup>13</sup> “The basic lessons of “Computing with Words” were subsumed conceptually to fuzzy sets, sometimes yielding ironic side effects: refusing to accept that Zadeh’s aim was to demythify the Number, accomplished mathematicians try to reconcile the Boolean infrastructure of IT with fuzzy sets theory moulding complex theories where instead of dealing with two integers, computer scientists have to consider the continuum of reals!” [64]. Worse: engineers too!

- **Holism.** The bond is twofold and strong: a) cognition is holistic and boundedly rational (*Wa4*, Q1, Q4); thus, any holistic approach is anthropocentric *par excellence*; b) if some predictable services could be canned (and handed over to machines) no service could be assessed (or adequately provided) if conceived as “decomposable” (validation is holistic, hence qualitative). Right-brain style supplements the limited left-brain algorithmic procedures (non-textual pseudocode for “Dialog” (Figure 8.8) with user-oriented comments, pattern recognition in “Interpret”, (Figure 8.6) image-based validation of mechanisms (Figure 8.5)). To restore the “holos” of the human brain, where BR comes from, *semiotics* is vital for answering questions like: “What is the horsepower of your interface?”

- **Agent-Orientation.** Having no agent in a work aiming to be “probably” the “first authentically agent-oriented thesis in Romania” impairs chances of passing on a research legacy – not even as open questions. Thus, the experience in trying – and failing – to implement complex interface agents is reduced to counterposing beliefs (in parentheses are ideas proved less important):

- For nontrivial services, provider agents must be bodiless because (for the time being) they are interface agents. (Bodiless agents are used when robots are unaffordable.)
- The fundamental hindrance in developing interface agents is caused by poor ontologies with temporal relations. (Agents are processes and popular IDEs don’t support for event-based thread synchronization and exception-based reactivity.)
- For a protoagent it is sufficient to have access to the interrupt subsystem and to build on it (Ada-like) exception handlers. (A software entity could be labelled as “agent” iff it is treated by the operating system as *thread*, i.e., as atomic, sequential, asynchronous, and dynamic entity.)
- Making decisions *in behalf* of humans, agents are inherently nondeterministic. (Robots are “agents with body” and can react deterministically to stimuli when polling their environment “Just-in-Time”.)

- **Transdisciplinarity.** Choosing GST as *Lingua Franca* for psychologically-oriented addressees was much more than a linguistic bridge as proved by [62], [61], despite their forced dilettantism.

- **Exploring memetic engineering.** Etymology extended both *time range* and *cultural space* of memplexes, proving their memetic stability and giving incentives for further research [26]. Example: “Robot” may be descended from a word that meant “slave labor”, and was later generalized to just “labor.” (Other examples of “concepts-memes” in 9.2.4.)

#### 9.2.4. Effects of Serendipity

In a thesis intrinsically tributary to heuristics – from *Zeitgeist* to topics to approach – most of such effects are hard to be distinguished from other thesis outcomes. On the other hand, due to the very manner of arriving at, they are either minor (skipped over) or of transdisciplinary nature (very shortened here). They are related to linguistics because most results are about etymology – including folk etymology – stemming from the

transdisciplinary approach above linking semiotics to memetics. Moreover, the three examples below are due to the research “etnolinguistic environment” they come from:

- *Order and computer science*. The German term "Rechner" proves an old connection between ordering and computing as mental processes. This research diRECTion (Rex, Recht, Rector, *reglage*) may lead to other links between paleo-mathematics and semiotics.

- *Strange linguistic coincidences*. Why are *counting* and *narrating* etymologically related? (Bernard Werber shows in “Encyclopedie Du Savoir Relatif Et Absolu” that there are word pairs similar to “count/recount”: “compter/raconter”, “zählen/erzählen”). Such tracks are worth to be followed proving the usefulness of “*not numerical mathematics*”.

- “*La țanc*”. If the term comes from the Dacian substratum, the linguistico-memetic exercise acquires a new transdisciplinary dimension: “*La țanc*” becomes the first substratum-based term that enters not only the IT idiom but perhaps the Romanian scientific terminology altogether.

### 9.3. OPEN QUESTIONS

Are they *significant* and *innovative* enough to be *questions* and to be let *open*? Thus, besides land marking a “new frontier” they should be read in the much modest key of the expected role the author can play in their future investigation: *future work* within the *EU2020 theses* cluster in 2012 (9.3.1), *medium-horizon CSITAO* research (9.3.2), and taking part in *other CSIT* research, labelled in Roman cartographic style with “*Hic sunt leones*” (9.3.3).

#### 9.3.1. Proposed for EU2020 theses

At this moment EU2020 theses means actually [26] and the following is seen from its perspective. Thus, the questions that remained open when this thesis was completed need a minirationale to be accepted as valuable research legacy: *Why is **Question** important to continuing education? Because **Supposition***

- **Q1**: *Linguistics (as part of Semiotics) is paramount. S1: Learning the mother tongue is obviously boundedly rational; teaching babies seems to be too. Moreover, the methods seem pervasive, language-independent, and almost unchanged since anthropogenesis.* Hence, teaching (meta)models should try to find out the methods mothers use (labelled or not as “dynamic knowledge”, or “skill”, or “know-how”, or even “life experience”).

To enable a smooth passing to the next open question, here is the telling instance of *logarithm*: *logos* ratio, reckoning + *arithmos* number.

- **Q2**: *Logarithms are “natural” no matter the base. S2: Decomposing “CSITAO”, logarithms are paramount for all parts: CS (binary logarithm for hardware), IT (common logarithm for conventional software), AO (natural logarithm for anthropocentric applications).* Indeed, the *high propensity to comparisons* should be investigated focused on the *logarithmic function*. Examples: a) the concept of equality is linked to both “*nil*” and

“zero”; b) Shannon’s unacceptable technocentric<sup>14</sup> *information theory* could survive in the post-industrial era *because* it is based on logarithms; c) nonverbal communication via *linear* input bars should be extrapolated through *psychophysical* input bars based firstly on logarithms but also on related (exponential, sigmoid, and so on) functions. Hence, teaching metamodels should shift the focus from conventional mathematics to modern, human-centred (non-numeric and even non-verbal) mathematics. (Of course, any mathematics is intrinsically *symbolic*, but was paleo-mathematics always *verbal*, even in solar clocks or at Stonehenge?)

- **Q3:** *Bounded rationality as twofold feedback. S3:* *Since BR is a – perhaps is THE – main cognitive mechanism and cognition involves inventiveness (e.g., “Eureka”-like effects) it is likely that BR could boost creativity (via positive feedback).* However, as shown: a) the link between BR and simplicity supports the prevalence of BR as psychological stabiliser (via negative feedback); b) it is challenging to prove that the same mechanism – here BR – could generate antithetic types of feedback. Hence, a GST based and cybernetic-oriented investigation should be carried out starting from the idea of local feedback loops within simulated discernable educational subsystems. Could “bipolar disorder” be a promising research path based on swapping between feedback loops, to diminish both “fruitless stability” and “vicious creativity”?

- **Q4:** *Boundedly rational perception of different times is vital for service providing. S4:* *This holds for decision making and for teaching too. The relationship between time and decisions is supposed to be that shown in Figure 9.1. Time is Newtonian (“Caesium Time”) only in simple situations where it does not matter significantly. When chaoplexity counts time must be perceived/managed by service users similarly to Bergsonian (“Carbon Time”) because nontrivial services (decision support, teaching, intensive therapy, etc.) are for humans also when they are provided by robots. From an AOSE stance it is necessary to find out what kind of time – and in what context – could be treated safely as preemptive resource. (Perhaps that requires investigating the time memplex based on memetic engineering.)*

- **Q4C (corollary):** *Establishing agents as non-algorithmic software entities<sup>15</sup>.* Only after answering Q4 could start a real debate regarding the status (or even the definition) of “*algorithm*” in a service-oriented society. That should: a) legitimate (non)algorithmic software and suitable mechanisms to implement it; b) let SOSE – or at least SOSE1 – to become a genuine branch of software engineering; c) promote developing “online DSS” based on “balanced decision making” (where “balanced” has the same meaning as in “balanced automation”).

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<sup>14</sup> Anthropocentric approaches would need rather something that evaluates *certainty* at the *destination* instead of *uncertainty* at the *source*.

<sup>15</sup>The FIPA standard defining the *agent* as *process* was a necessary and huge step forward but it is obviously not sufficient for boosting a paradigm shift. Indeed, it is almost a selfcontradiction: standards are overlooked mainly *because* they conserve all obsolete facets of prevalent paradigms.

### 9.3.2. Proposed for medium-horizon CSITAO research

Noticeably, most open questions regard the fifth thesis objective. Indeed, the possibility to build Computer Science rather on Semiotics than on Mathematics seems to be more than a single paradigmatic shift. Thus, to persist in using names metaphorically, before accomplishing the shift from *Kelvin* to *Zadeh* it would be pointless to try the shift from *Zadeh* to *Lao Tzu*. Though, considering the (self)evaluation as well as the open questions above, the technically closed objective could (and should) become the kernel of a future CSITAO thesis, removing its confinement to exploration. Some key facets are the open questions unanswered or uncared for within EU2020 research:

- Is the archetypal *yin-yang* symbol (suggesting both *sigmoid* and *linear nonseparability*) just a metaphor or is it mathematically significant?
- What is the relationship between BR, synergy, nonverbal communication, and psycholinguistics? What relations in nontextual/nonverbal ontologies are applicable in SOSE?
- Why are so many exact trigonometric formulae or infinite series to express the golden ratio when no user cares about them?
- Close related question: on the other hand, why the simplest way to get an idea about the numeric value of the ratio is to calculate not the geometric ratio itself but the quotient of successive Fibonacci numbers? (The answer looked for regards the role of time in boundedly rational approaches to risk management in a post-industrial society.)
- Why is “Innumeracy” a much newer concept than “Illiteracy” and what is their relationship to BR? (The investigation should consider the seminal work of Gigerenzer, as well as the ideas of Nadin, Nake, and Paulos.)
- What about reviving other semiotic-oriented unfinished research regarding Computer-Aided Semiosis or “Silicon time” based on Husserlian “thick time” (for a primeval consciousness of bodiless agents)?
- Is the danger of “*semiotic endogamy*” real? One of the possible side-effect implication chains of modern IT is: Semantic Web → Social Networks → Folksonomies → Linguistic Closure. Taking into account Wittgenstein’s caveat that the limits of our language are the limits of our world, could GST act as “domain mini-ontology-Kernel”?

### 9.3.3. Proposed for other CSIT domains. “Hic sunt leones”

This section is postponed and contains are only keywords or suggestions:

- a) Anthropocentric assessment of information oriented towards plausibility at destination
- b) CSIT oriented mathematics of time or at least “space-time” as in the d’Alembertian.
- c) Eco “*intentio*-ns” vs time: *auctoris/past*, *operis/present*, *lectoris/future*
- d) Does autonomous behaviour imply initiative or control? Does it imply both or none of them?
- e) Are *educational* and *situational* chaoplexity equivalent? (Could e-teaching and DSS use the same SOSE tools?)

## 9.4. SUMMARY OF ORIGINAL CONTRIBUTIONS, REFORMULATED

The main results refer to the following:

- **Concepts:** a) *Bounded Rationality* was: *redefined as polysemantic* lasting psychologic feature, *mechanism* for decision support based on incomplete information, *strategy* for continuing education (sections: 4.1, 4.2, 4.3, 5.1.1, 5.1.2, 5.3.3, 5.3.4, 7.1.1, 7.1.3); *expressed coherently* in GST for transdisciplinary (sections: 5.1.1, 5.1.2, 5.2.4, 5.3.3, 5.3.4); substantiated as stabilizing *mechanism* for, and *connection* between subsystems of continuing education (sections: 7.1.3, 7.1.4, 7.3.2, 7.3.3). b) “*Just-in-Time*” („*la țanc*”, *JIT*) was: *upgraded* from the status of label for an essential inventory strategy (in the industrial era) to a *sine qua non* requirement for service providing (in the post-industrial era) (sections: 3.4.1, 3.4.2); *semantically enriched* (as superseder of “*real time*” it becomes a *raison d’être* feature of any service and of any decision making) (in section: 3.4.3); *Merged with bounded rationality*, the compound concept “BR + JIT”, allowed adding to Zadeh’s assertion on precision: “*Rationale 3: precision is unnatural*” (from a BR stance) and “*Rationale 4: precision is harmful*” (from a JIT stance) (sections: 3.2.3.1, 4.2.3, 5.4.3, 6.2.3, 8.2.1, 8.4.2).
- **Mechanisms:** a) “*Balanced decision*” in chaoplex situations. Swapping between *automatic* control (robots decide deterministic based on algorithms, time is circular: “*return*” restarts a loop) and *manual* control (humans decide nondeterministic, based on BR (time is irreversible: “*return*” is mandatory for service finishing) (sections: 6.3.4, 7.3.4.2, 8.3.2, 8.3.4); b) *Service-oriented decision-making framework*. Meaning: anthropocentric (multimodal, analog interaction), oriented on decisions based on uncertainty (future contingent, abduction, procrastination), semiotics (nonnumeric, nontextual or nonverbal software), non-Chrysippean (multiple alternatives replacing “IF” by “SWITCH” with “DEFAULT”) (sections: 6.3.1, 6.3.2, 6.3.3, 8.2.2, 8.2.3, 8.3.2, 8.3.3, 8.4.3.1); c) *Multifunctional bar for analog input oriented on decisions* is: universal (usable for all kind of uncertain input, and for all psychophysical laws governing cognition), applicable to real-world problems independent of any paradigm, implementable using conventional algorithmic software engineering (sections: 6.1.2, 6.2.1, 6.2.3, 6.2.4, 8.2.1, 8.2.3); d) *Illustrating elements of Semiotic-Oriented Software Engineering* with outworn IDEs (object oriented, without exception handling, with primitive multithreading) (sections: 8.4.1, 8.3.2).
- **Approaches:** Are based on: a) *Anthropocentrism* (symbolic interfaces, reducing cognitive complexity and hiding structural complexity); b) *Holism* (cognition is holistic and boundedly rational, no trivial service could be assessed (or adequately provided) if conceived as “decomposable”, validation qualitative); *Agent-Oriented* (agents are bodiless because they are interface agents); *Transdisciplinarity* (Choosing GST as *Lingua Franca* for psychologically-oriented addressees); e) *Exploring memetic engineering* (memetic stability verified through etymology,



cultural spaces, compared linguistics) (sections: 3.2, 5.1.1, 5.1.2, 5.2.3, 5.2.4, 5.4.3, 5.4.4, 6.1.2, 7.1.3, 7.3.4, 8.1.1, 8.3.4).

- **Effects of serendipity:** especially in Romanian terminology („la țanc”, innumeracy) (in section 7.4.3).

*In nuce*, this thesis should be regarded as having attained its target if the concept of “*Bounded Rationality*” will be subject to a semantic inversion for all stakeholders involved (first of all decision makers) being perceived as versatile human-oriented modelling mechanism instead of hard to avoid multifaced hindrance.

# Author's Work

## Glossary

AW1. Bărbat, B.E., R.D. Fabian, C.I. Brumar. *CSITAO Carnap-like Glossary*, [http://bcu.ulbsibiu.ro/digitale/doctorate/glossary\\_csitao.pdf](http://bcu.ulbsibiu.ro/digitale/doctorate/glossary_csitao.pdf)

## I. Articles in ISI journals with impact factor

AW2. Ralf Fabian, Misu-Jan Manolescu, Loredana Galea, Gabriela Bologna, *Bounded Rationality through the Filter of the Lisbon Objectives*, International Journal of Computers, Communications & Control, IJCCC, Băile Felix-Oradea, Romania, 2010, Agora University Editing House, ISSN 1841-9836, E-ISSN 1841-9844, Vol. V (2010), No. 5, pp. 710-718.

## II. Transdisciplinary papers related to the EU2020 targets published in international proceedings other than CSIT

AW3. Constantin Oprean, Ralf D. Fabian, Cristina I. Brumar, Boldur E. Bărbat, *Bounded Rationality for "Just In Time" Education*, 2nd World Conference on Psychology, Counselling and Guidance, Procedia-Social and Behavioral Science Journal, May, 2011, pg. 983-987 Antalya, Turkey, ELSEVIER, ISSN: 1877-0428

AW4. A.E Lascu, Ralf Fabian, *e-Semiotics for Romanian-German Transcultural Interfaces*, The Good, the Bad and the Unexpected: The User and the Future of Information and Communication Technologies, Sapio, Bartolomeo et al. (eds), Moscow, Russian Federation, May 2007: Conference Proceedings. Brussels, EU-COST Action 298 Participation in the Broadband Society, VOL II., 2008, pg. 737-742, ISBN: 978-92-898-0042-6

AW5. C. OPREAN, C.V. KIFOR, B.E. BĂRBAT, A. BRAȘOVEANU, R.D. FABIAN, *Bounded Rationality in Computer Science Curricula*, Proceedings of the 2010 International Conference on Frontiers in Education: Computer Science & Computer Engineering, FECS 2010, eds. Hamid R. Arabnia, Victor A. Clincy, Azita Bahrami and Ashu M. G. Solo, July, 2010, Las Vegas, Nevada, USA, CSREA Press, ISBN 1-60132-143-0, pp. 135-140

AW6. C. Oprean, C. I. Brumar, C.V. Kifor, R.D. Fabian, B.E. Bărbat, *Post-Industrial Quality for Sustainable Development*, Proceedings of the 1st International Conference on Quality and Innovation in Engineering and Management, Cluj-Napoca, March, 2011, pg. 159-162.

AW7. Boldur E. Bărbat, Ralf Fabian, Cristina Brumar, Roxana Muntean, *Bounded Rationality and approximation in modern artificial intelligence*, Proceedings of The International Workshop - New Approaches, Algorithm and Advanced Computational Techniques in Approximation Theory and its Applications, Sibiu, Romania, September, 2007, pg. 64-67, Lucian Blaga University Press, ISBN 978-973-739-949-2.

### III. Paper in Thomson Reuters indexed Journals and Proceedings

- AW8. Ralf Fabian, Alexandru-Nicolae Marcu, *Natural language processing implementation on Romanian ChatBot*, Proceedings of the 9th WSEAS International Conference on SIMULATION, MODELLING AND OPTIMIZATION, Budapest Tech, Hungary, September 3-4, 2009, pg. 440-445, WSEAS Press, ISSN: 1790-2769, ISBN: 978-960-474-113-7.
- AW9. Ralf Fabian, Daniel Hunyadi, Emil. M. Popa, *Syntactic pattern model classification with total fuzzy grammars*, Proceedings of the 12<sup>th</sup> WSEAS International Conference on Computers - New Aspects of Computers, Heraklion, Greece, July 2008, pg. 317-321, Published by WSEAS Press, ISSN 1790-5109, ISBN 978-960-6766-85-5.
- AW10. Emil. M. Popa, Ralf Fabian, Cristina Brumar, *A Bounded Rational Review of Approximation and Undecidability in Economic Modelling*, Proceedings of the 12<sup>th</sup> WSEAS International Conference on Computers - New Aspects of Computers, Heraklion, Greece, July 2008, pg. 303-308, Published by WSEAS Press, ISSN 1790-5109, ISBN 978-960-6766-85-5.
- AW11. Ralf Fabian, Pleşca Sorin, *Stigmergy-based Software Toolkit for Virtual Enterprises*, Proceedings of the 11<sup>th</sup> WSEAS International Conference on COMPUTERS, Agios Nikolaos, Crete Island, Greece, 2007, pag. 438-441, ISSN 1790-5117, ISBN 978-960-8457-95-9.
- AW12. Vasile Crăciunean, Cristina Elena Aron, Ralf Fabian, Ioan-Daniel Hunyadi, *Multi Level Recursive Specifications for Context Free Grammars*, Proceedings of the 11<sup>th</sup> WSEAS International Conference on COMPUTERS, Agios Nikolaos, Crete Island, Greece, 2007, pag. 275-280, ISSN 1790-5117, ISBN 978-960-8457-95-9.
- AW13. Vasile Crăciunean, Ralf Fabian, Ioan-Daniel Hunyadi, Emil M. Popa, *Fix point internal hierarchy specification for context free grammars*, Proceedings of the 11<sup>th</sup> WSEAS International Conference on COMPUTERS, Agios Nikolaos, Crete Island, Greece, 2007, pag. 247-251, ISSN 1790-5117, ISBN 978-960-8457-95-9.

### IV. Papers indexed by other international databases

- AW14. Ralf D. Fabian, Dana Simian, *Bounded Rationality and Visual Pattern Transmission*, Proceedings of the European Computing Conference, Paris, France, April, 2011, WSEAS Press, ISBN: 978-960-474-297-4, pg. 421-426
- AW15. Ralf Fabian, Emil Marin Popa, *Fuzzy Extension on Context-free Grammars*, Proceedings of 2nd Annual SEERC Doctoral Conference, Thessaloniki, Greece, June 2007, SEERC Publisher, ISBN: 978-960-89629-5-8  
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- AW16. Vasile Crăciunean, Ralf Fabian, Emil. M. Popa, *Total Fuzzy Grammar Driven Architecture for Intelligent Software Systems*, WSEAS Transactions on Computers, Issue 2, Volume 6, February 2007, pag. 248-253, ISSN 1109-2750.
- AW17. Vasile Crăciunean, Ralf Fabian, Emil. M. Popa, *Algorithm for Optimal Decomposition of Software Applications*, WSEAS Transactions on Computers, Issue 2, Volume 6, February 2007, pag. 242-247, ISSN 1109-2750.
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- AW19. Ioan-Daniel Hunyadi, Emil M. Popa, Ralf Fabian, Ionela Mocan, *Translation for intermediate code*, Proceedings of the 8<sup>th</sup> WSEAS International Conference, Mathematical Methods and Computational Techniques in Electrical Engineering (MMACTEE), Bucharest, Romania 2006, pag. 93-98, ISSN 1790-5117, ISBN 960-8457-54-8.
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- AW25. Ralf Fabian, *Online study program design and deontological issues*, International Workshop E-learning Aspects in Medicine and Nursing, MEDINF 2007 e-Health Days in Sibiu, Medical Informatics, Telemedicine, Biostatistics and Clinical Epidemiology, organized in the frame of the research grant DANTE CEEEX 73-2006, November, 2007, ISBN 978-973-739-592-4, Lucian Blaga University Press.
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