Symbiotic Thinking … for Cognitive Modeling as Well

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Abstract— **The choice of a design paradigm influences the tools that may (or have to) be used and also the level of ambitions that may (or have to) be envisioned. This paper suggests, in Cognitive Science, exploring a particular design paradigm enabling to conceive cognitive theories that guarantee a possibility for future extensions while preserving the atemporal character of the previous achievements. One of the essential tools of this design methodology is symbiosis as a particular composition of building parts of such evolving theories. We have used these topics in a formalization of creative processes involved in the design of Symbiotic Recursive Pulsative Systems, as they are performed while designing a methodology for Automated Program Synthesis from formal specifications in incomplete domains. The paper thus concerns modeling human mental processes as well as human reasoning mechanisms.**

Keywords— Cartesian Systemic Emergence; Symbiotic Recursive Pulsative Systems; Symbiotic Thinking; cognitive models; implementation of human reasoning mechanisms.

I. INTRODUCTION

In contemporary science, a multidisciplinary systems modeling is usually performed by selecting some available logically justifiable (thus 'mathematical') tools and by adapting these tools to purposes for which these tools were not originally designed. As has been known already to Francis Bacon (see [1], p. 68), this approach may lead to artificial difficulties. More recently, Bertalanffy expressed the need for a change as follows: "It may be preferable first to have some nonmathematical model with its shortcomings but expressing some unnoticed aspect, hoping for a future development of a suitable algorithm, than to start with premature mathematical models following known algorithms and, therefore, restricting the field of vision" [3], p. 24.

We have relied on Bertalanffy's suggestion in our work with a design of a particular problem-solving system, namely a system that constructs recursive programs from formal specifications in incomplete domains (called here Program Synthesis in Incomplete Domains, PSID, for short). We realized that a necessary condition for the success of our task is including 'symbiosis' into the design of the system (thus conceiving a symbiotic system) and to our scientific reflection as well (thus performing 'symbiotic thinking'). Roughly speaking, symbiosis concerns a particular composition of the parts of a system. Namely, the essential feature of a symbiotic composition is that, when eliminating an arbitrary part of a symbiotic system, not only the whole system but also all the remaining parts collapse, i.e., the system and its parts cease to exist or are mutilated. A typical example of a symbiotic system is provided by Peano's definition of Natural Numbers (NAT). If we use the symbol ♦ for symbiotic compositions, a formal representation of the systemic definition of NAT reads as: NAT = 0 ♦ Suc ♦ NAT, where Suc is the successor function. If we eliminate one part from this system, for instance 0, we may no more speak of Suc nor of NAT as such. This example illustrates that, while it might not be obviously noticeable, symbiosis is present in formulating primitive notions (such as 0, Suc, Nat) of deductive theories.

The exactness required by mathematical sciences (see [12]) is not suitable for handling symbiosis. This maybe explains why Cognitive Science (CS) relies on modular tools and formulates modular models [2]. In this paper, we want to point out the advantage of designing evolving symbiotic systems/models not only in Computer Science (as illustrated by our work in PSID) but in CS as well. Indeed, such an evolving teleological orientation (*teleos*, lat. "end") of CS research allows handling, in a creative way, problems that are out of the scope of modular systems. For instance, consider the goal specified informally by the following sentence:

(g1) "Construct a scientific model of the human brain that solves all the questions and problems related to a formalization of the brain mental processes".

Researchers in CS will certainly argue that this goal is impossible. We would like to point out that this notion of 'impossible' is related to the present scientific knowledge, scientific tools and models. In this paper, we will present some notions and tools that diminish the strength of this contemporary verdict 'impossible' to a somewhat weaker notion of 'reasonable and achievable, provided that we change our paradigms, tools and that we put in an adequate effort'. Of course, a trade-off of this new approach is replacing the requirement of exactness by the requirements of rigor, control and prevention. By control is meant here the requirement to consider all secondary effects of the evolution in the process of construction of a particular system so that the constructed system needs *no future maintenance*, as it is, for instance, the case for Peano's axioms. By prevention is meant here some careful anticipation of possible future practical needs, opening thus a way to a smooth extension of a previously, practically sufficient system. This can be illustrated by a smooth extension of NAT up to complex numbers. In other words, the acceptance of new essential values leads to interesting by-products, namely, to a creative freedom enabling to consider evolving systems and to non-obsolesce of these systems at each stage of its evolution.

Concerning these essential competitive returns of considering symbiosis in the systems design and modeling,

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our aim in this paper is to share the essential knowledge we have used in PSID and that we deem useful also for CS.

The paper is structured as follows. Section II specifies the context of this paper. Section III introduces some fundamental notions that are necessary for understanding the topic of this paper. Section IV presents the main problems related to the use of Symbiotic Thinking in creation and modeling symbiotic systems. Finally, Section V presents related and future work.

II. THE CONTEXT

PSID as well as the brain are complex problem-solving systems. Therefore, it is necessary to point out how symbiosis is related to basic problem-solving paradigms. In this section we are going to recall two of these paradigms. We will explain also how symbiosis and modularity are related to these paradigms. Then, we present Cartesian Systemic Emergence as an effort to formalize a particular kind of scientific creativity.

A. *Paradigms*

Let us briefly draw the difference between modular and symbiotic Paradigms.

In a *modular* system, the parts (called *modules*) of the system are units, entities or operations that can exist all by themselves, though in the modular system they are intended to be used together. Modular systems are designed usually via the paradigm that can be represented by the following formula:

$\forall$ Problem $\exists$ System solves(System,Problem). (P1)

(P1) states that for any problem Pb_i one can build at least one system (or a module) S_i able to solve Pb_i. Usually, S_i is not able to solve a problem Pb_j, for $j \neq i$. This is why we call here heuristics such solutions. Relying on (P1) while constructing a system leads to a library of particular heuristics. One can therefore design a modular system S that is a modular composition of S_i that were previously built. Of course, this does not imply that S necessarily represents a global solution for all possible problems Pb_j, since a global solution is a unique universal method for all problems. Paradigm (P1) is useful when one of the main goals is to guarantee a simple maintenance of resulting systems [18] [13]. Most system designing approaches are thus based on this paradigm [6] [13] - [15] [18].

In contrast to modular systems, the creation of symbiotic systems usually relies on the paradigm expressed by the following formula:

$\exists$ System $\forall$ Problem solves(System,Problem). (P2)

(P2) states that one may build at least one system that will solve all problems. The construction of a system via (P2) largely differs from the one of via (P1). (P2) has to result in a single universal system S. For instance, Peano's arithmetic for NAT is an illustration in which (P2) has been used. Note that this illustrates that it is meaningful to rely on (P2) while creating a global system, even though the resulting system may not verify the completeness requirements. In other words, Gödel's results [12] are not an obstacle for the use of (P2) while designing real-world problem-solving systems.

In this paper, the systems conceived via paradigm (P2) are called P2-systems and the solutions to a problem conceived via (P2) are called P2-solutions. Recall once again that the main difference between a P2-system and a P1-system lies in the fact that a P2-solution is a single unified universal method while a P1-solution is a modular library of heuristics.

B. *Cartesian Systemic Emergence*

In [5], the author gives an example of a highly smart people group failure to solve a multidisciplinary problem. The main reason for this failure is a lack of effort to build a common vocabulary allowing to integrate skills and knowledge of this group. This illustrates that collaboration on a multidisciplinary topic, as are PSID and (g1), being itself a complex dynamic system (see [21]) requires a preliminary elaboration of a 'meta' action-oriented theory to avoid failures due to missing directed integration of multidisciplinary knowledge and skills. Being aware of the importance of developing and studying symbiotic P2-systems as well as a rather unusual character of *symbiotic* collaborations, we felt necessary to create solid foundations for this new type of research. We call Cartesian Systemic Emergence (CSE) the theory intended to represent these foundations [9]. In [22], we present a preliminary toy example to illustrate CSE in action.

In this paper, we work exclusively in the context of symbiotic P2-systems. The next section presents the most important notions necessary for understanding the complexity and the essential advantages (and drawbacks) of considering symbiotic systems.

III. SOME FUNDAMENTAL NOTIONS

As said above, CSE is intended to become a theory to represent the foundations enabling to understand, perform and evaluate research on symbiotic P2-systems, be it in the form of a design or of a modeling of symbiotic P2-systems. More accurately, the goal of CSE is to formalize strategic aspects of human creation of *informally* specified *symbiotic deductive-like problem-solving systems* in incomplete domains following our *pulsation* model. This formalization is performed to prepare fundamentals for *designing automated tools* that help humans or that may even be able to perform alone this complex task. The goal of CSE is expressed in terms of five fundamental notions.

Since the goal of CSE is to be considered in a P2-framework, i.e., CSE aims at a formalization that is a symbiotic P2-system. Therefore, all the fundamental notions that we need to define are symbiotically interrelated. As a consequence, each of these fundamental notions cannot be clearly described without referring to the other fundamental notions. This is why, in order to introduce such complex descriptions, we will present, at first, a rough description of their meaning independently of their aim to represent a basis of a P2-system. Such a rough description can also be used in the context of modular P1-systems.

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As roughly described above, the symbiosis of parts of a system means that, if even only one of these parts is eliminated, not only the system collapses but also all the other symbiotic parts collapse as well. An informal specification of a system is a description of this system that is somewhat vague, i.e., what the words in this description exactly mean may be unclear. Standard deductive-like problem-solving systems are systems that have to be defined exactly by their corresponding axiomatic system. Incomplete domains are domains that are insufficiently formalized in the sense that there might exist several different interpretations corresponding to the considered formalization of the domain. Pulsation is a model for a particular kind of systems evolutive improvement.

We will now provide more details about these notions.

A. Symbiosis

In the design of a deductive-like problem-solving system, we need to be aware of a particular interdependence, called here symbiosis, of the parts of the resulting system. By ***symbiosis***, we understand a composition of several parts that is vitally separation-sensitive. By *vital separation-sensitivity* of a composition, we mean that eliminating one of its parts has three possible consequences. It may be a complete destruction or a non-recoverable mutilation or uselessness of the remaining parts. This implies that the divide and conquer strategy, as well as analysis and synthesis are inappropriate tools when creating and observing symbiotic systems. Symbiosis is therefore different from synergy that is a mutually profitable composition of elements that are not destroyed nor mutilated by separation.

A well-known picture that may be used for an intuitive understanding of symbiosis is the well-known so-called ‘duck-rabbit’ illusion. This picture may be seen as a symbiosis of two parts, namely the ‘rabbit’ and the ‘duck’. In this picture, the result of removing one of its parts (the ‘duck’, for instance) gives ‘nothing’. In other words, the ‘rabbit’ disappears as well. This is an example of what we mean by ‘destruction’ in our definition of symbiosis.

The symbiotic parts, however, do not necessarily need to coincide in the final symbiotic object as it is in the case of the just mentioned picture. They may have a symbiotic, possibly a hidden one, intersection that makes their whole symbiotic. From a systemic point of view, symbiosis of a system is embodied by the *vitally separation-sensitive interdependence* of all the notions and the parts of this system.

B. Informal specification

In the framework of CSE, an ***informal specification*** of a system is a description of this system by a *sentence* in which occur terms that are not yet exactly defined; they are underspecified. When considered out of a particular context, such a description, i.e., informal specification, may even seem absurd or the goal specified by it may seem impossible to reach. These terms in which a given concrete informal specification is expressed will evolve during the system construction. In other words, depending on some constraints and opportunities that will arise during the construction of the system, the meaning of the terms used in the starting specification will evolve and will make a part of the solution. The initial ambiguity of terms occurring in a given informal specification is eliminated by the provided solution. Their evolution will also bring an exact specification of the context to be considered.

For instance, let us consider the above goal (g1). The notion of ‘brain’ is specified here informally, since no definite agreement has been provided as to what aspects, functions, *etc.* have to be considered. The same holds about the notion of ‘model’, ‘solve’. In order to point out that these notions will evolve during the research on this imprecisely formulated goal, in the framework of CSE, the notion of informal specification needs to be completed by stressing the difference between the notions of formalized (rigorous) and the one of formal (exact) specification. In CSE, a ***formalized specification*** is an intermediary state in the progress from informal to formal specification. It consists in a collection of not yet uniquely defined definitions and not yet exactly defined tools that plausibly point at a successful completion process. In such a completion process, some inventive steps may still be needed to complete these inexact but rigorous working definitions and tools so that their use and their evolution, through suitable experiences, lead to their final form (i.e., their exact form). A formalized specification allows thus to perform rigorous thinking. In CSE, a ***formal specification*** then consists in a complete solution represented by the working system and the complete knowledge necessary to the system construction, i.e., a particular kind of meta-knowledge. These all are needed in order to be used in further evolutive improvement. The notion of evolutive improvement will be introduced in Section D.

The notion of informal specification plays an important strategic role in the Multidisciplinary Systems Design and Modeling (MSD) since it fulfills the role of balance between rigor and freedom known to be necessary in complex systems for them to evolve, transform and adapt [21].

To give illustrations of a formalized and of a formal specification, we need to introduce the notions of deductive-like problem-solving system (in Section C) and of Pulsation (in Section D). These notions will help us also better illustrate what we mean by symbiosis.

C. Deductive-like Problem-Solving Systems

In P2-oriented MSD, explaining what we mean by a deductive system is important, since the goal of CSE is to build a deductive-like P2-system formalizing human creation of P2-symbiotic systems. By ***deductive systems*** we understand a particular kind of axiomatic systems in the sense that these systems formalize, in a compact finite way, the knowledge about a Real World Situation (RWS) with the aim to handle this knowledge in an efficient uniform way.

Peano’s Axiomatic Definition (PAD) of NAT and Euclid’s Geometry (EG) are the best-known examples of deductive systems. They make a part of what has been called, in the above section, a formal specification.

As can be illustrated by the evolution of PAD and EG, a formalization of an RWS leading to a deductive system consists of a ‘selection’ of essential primitive notions and axioms representing the essential relationships among these notions.

Primitive notions are the notions that are *not* defined with the help of previously defined notions. Before a full formalization of an RWS, the meaning of these notions is specified, informally, by a *large experience* in RWS which shows that they are useful and essential for considering RWS. For instance, if we consider NAT, a large experience in natural numbers shows that the primitive notions in a formalization of NAT are not only 0 and Suc, but also NAT themselves. Indeed, we cannot (or do not know how to) provide a clear understanding of what we mean by natural numbers by referring to other already defined notions. The primitive notions of a deductive system are, in principle, symbiotic. For instance, as said above for NAT, we cannot specify informally what 0 signifies in another way than by referring, in this informal description, also to Suc and NAT.

As said above, ***axioms*** of a deductive system express the statements about the relationships among the primitive notions. The essential particularity of these relationships is that, together, they provide a formal definition of all the primitive notions. In other words, it is not a particular axiom that defines a particular notion, all axioms are symbiotically necessary to provide a clear understanding (and thus a definition) of the meaning of a particular primitive notion.

Since the primitive notions of PAD and EG are symbiotic, their axioms could not be determined via (P1). The axiomatic constructions of both these systems were determined via (P2) since in both cases the aim was to obtain one global system describing respective RWS.

We shall now informally define what we mean by a deductive-like P2-symbiotic system.

By a ***Deductive-like P2-Symbiotic System*** (P2-DSS) we mean a system such that its primitive notions are specified informally and the essential relationships among them, expressed by a finite number of axioms, provide their exact definition.

Note that, to the best of our knowledge, the symbiotic character of the primitive notions and the axioms of a deductive system has never been mentioned in the literature before.

D. Pulsation

Pulsation is a model for evolutive improvement, including creation, of practically complete systems that are concerned with the factors of control and prevention. In other words, pulsation provides a rigorous framework for the completion process of incomplete systems. In similarity to the infinite sequence which is used in [10] to *construct* Ackermann's function (see its standard definition in [20]), Pulsation relies on a *construction* of a potentially infinite sequence of systems that might be used to construct a global *'Ackermann's system'* that contains all of these systems. In our work, by Pulsation we thus understand a progressive construction of a potentially infinite sequence S_0, S_1, …, S_n, S_{n+1}, … such that

1. S_0 is the initial informal specification,
2. S_i, for $i > 0$, is an incomplete, but a practically complete deductive system,
3. $S_i \subset S_{i+1}, S_i \neq S_{i+1}$ (for i = 0, 1, 2, …), and
4. an infinite limit of this sequence represents an ideal, complete deductive system S.

We say here that S_{i+1} is a *practical completion* of S_i (for i = 0, 1, 2, …). The fourth requirement can formally be written in the form

$$\lim_{n\to\infty} S_n = S. \tag{1}$$

Note that, in a potentially infinite sequence S_0, S_1, …, S_n, S_{n+1}, … , S_0 is an informal specification, while S_1 is a practically complete system. Therefore, the transition from S_0 to S_1 is the most difficult process, since it requires to go from informal specifications to designing all the formal specifications of the notions, the rules and the on-purpose tools that are to be used to describe S_1. The transition from S_i to S_{i+1} is an easier task not only because experience with handling symbiotic parts has been further developed but also because in this transition the notions and the tools of S_i are considered in their formalized version. CSE is being developed to provide a reasonable solution to these two kinds of problems as well.

E. Complementary Notions and Remarks

In the MSD-framework, to consider the above-introduced notions as symbiotically interrelated, i.e., defined in terms of each other, is important for understanding the process of construction of a P2-DSS. For an RWS of a Problem-Solving System (PbSS) expressed by a P2-DSS, the *primitive notions* are specified by informal specifications of the goal of each primitive notion in the context of PbSS. In other words, the informal specifications of primitive notions express the '*what*' behind these notions. The axioms of P2-DSS, conceived for PbSS, express then the '*how*' corresponding to each informally specified '*what*'. In other words, the *axioms are procedures* of PbSS. These procedures are defined symbiotically in a similar way as it can be perceived from the symbiosis of the axioms in PAD.

This has a large implication for understanding the process of construction of a P2-DSS. Namely, it is necessary to understand that the process of specifying the primitive notions is symbiotic with the process of 'introducing' the axioms. In other words, the primitive notions and the axioms 'emerge' together in the process of construction of P2-DSS for a considered RWS.

Above, we have introduced the fundamental notions that contribute to understanding CSE and ST. These notions allow us to introduce, in multidisciplinary systems design, the notion of *Symbiotic Recursive Pulsative Systems* (SRPS) that are, by definition, systems that are implicitly or explicitly symbiotic, that are recursive either by systemic recursion or by the process of evolutive improvement via Pulsation, and that are pulsative, whenever the model of Pulsation (together with the notion of practical completeness) is used in their design. To point out that SRPS are developed via paradigm (P2), we may call them P2-SRPS.

Let us consider an example of a symbiotic system for which we put symbiosis together with recursion, Pulsation and P2-paradigm. Thus, let us consider the above informal specification (g1) from CS. Now, we may ask whether a solution might not be something like

$$\lim_{n \to \infty} \mathrm{Brain}_n = \mathrm{Brain}, \qquad (2)$$

where

$$\mathrm{Brain}_n = \mathrm{Left\_Brain}_n \blacklozenge \mathrm{Right\_Brain}_n \blacklozenge \mathrm{RNK}_n \ \&$$
$$\mathrm{Left\_Brain}_n = \mathrm{Brain}_{n-1} \blacklozenge \mathrm{RNK1}_n \ \&$$
$$\mathrm{Right\_Brain}_n = \mathrm{Brain}_{n-1} \blacklozenge \mathrm{RNK2}_n$$

Here, RNK_n is a new knowledge related to symbiotic composition of left and right brains in the n-th pulsation step, $RNK1_n$ and $RNK2_n$ are relevant new knowledge extending, by the process of practical completion, the previous knowledge respectively about $Left\_Brain_{n-1}$ and $Right\_Brain_{n-1}$. This means that, with respect to mental processes instead of studying the brain as a synergy of two elements (left and right brain) [2], it might be interesting to explore the potential of this new symbiotic paradigm. Note also that (2) represents a recursive model of the brain, which explicitly indicates its evolutive character.

The next section presents more information about ST.

IV. SYMBIOTIC THINKING

The goal of ST is, in the process of CSE, to create symbiotic compositions as well as to contribute to a relevant suggestion of missing parts relative to a designed P2-SRPS system. Thus, as a by-product of this goal, CSE also aims at a formalization of a particular kind of scientific invention of new scientific concepts (different from scientific discovery [4]) in the design process of a P2-SRPS system. ST is therefore the most complex facet of CSE.

In order to describe ST, let us consider the goal of constructing a Problem-Solving System (PbSS) specified by an Informal Specification (InfS). Note that, as far as mental processes are concerned, the human brain can be considered as a real-world instance of a PbSS. As said above, ST is a conscious construction process aiming at two goals. One goal deals with a relevant evolving symbiotic composition of PbSS's parts. The second deals with a relevant suggestion of missing parts. Achieving these two goals indirectly leads to a progressive refinement and completion of the notions in InfS.

ST is indeed very complex since, in the PbSS's design process, it simultaneously handles three tasks. The first deals with the symbiotic character of all parts of CSE. The second does with the symbiotic character of all parts of a PbSS (even those that are not yet specified in the construction process). The third deals with the symbiotic character of the environment for which PbSS is being developed.

In the process of constructing a PbSS, some elementary parts of the system are specified by the needs that have been recognized in a relevant preliminary theoretical and experimental study of the given informal specification InfS. The consideration of the suggested parts as being informally specified and symbiotic allows

(a) a freedom to design them in an original manner,
(b) letting these parts evolve relying on the requirements that will appear in the design process,
(c) their imperfections (from a theoretical or practical point of view) to be compensated by the other parts of the system or by the system itself,
(d) a natural emergence of minimal forms of complementary constraints on the system, on its parts or on the environment.

These particular competitive advantages of ST and CSE, provided an adequate effort, *enlarge* the possibilities of MSD in that they hand over realistic goals that have before been considered unreachable.

For instance, for brain modeling, (a) and (d) together reflect considering complex experiences from the start so as avoiding simplicity factors to become, in future, obstacles to an effective ideas-activating process. The advantages (b) and (c) together reflect accepting the fact that research on symbiotic systems itself is a complex system [21] and thus it cannot be evaluated from a short-sided perspective of short or mid-term projects, as it is unfortunately usual in contemporary science.

Note that, in this section, our aim is solely to present the role of ST and its advantages for designing a P2-SRPS. We will not describe here its execution. The reason for this restriction lies in the fact that it would also require a detailed description of the strategic aspects of Program Synthesis from underspecified informal specifications in incomplete domains. We shall, therefore, address this topic in our future work.

V. RELATED WORK

In [9], we have pointed out that CSE might well be part of a challenge for CS, namely by developing CS models that capture all the essential characteristics of CSE, by finding methods and tools to study the emergence process in an active performance and developing on-purpose computational models for this particular way of thinking. Here we can enlarge our observation of CS problems that are similar to ST to conceptual blending as studied in [8]. As expressed by Fauconnier and Turner, conceptual blending is a non-deterministic intuitive process performed on small conceptual pockets constructed for purposes of local understanding and action ([8], p. 40), In contrast to this, ST performs consciously a goal-oriented symbiosis taking into account all the aspects (local as well as global, methodological as well as teleological, *etc.* as described in the above section).

Furthermore, if Wittgenstein points out, in [19], the interest for duck-rabbit illusion from the philosophical and psychological points of view, thus formulating a challenge for CS from perception modeling perspective of unusual 'objects', we point out here the challenge of modeling technological aspects of *creating/modeling* symbiotic systems.

Even though the topic of considering ST (and CSE) in CS is challenging, we are convinced that a strong desire or need to solve problems that CSE and ST suggest to CS will lead soon or later to fruitful empowerment of CS.

VI. CONCLUSION AND FUTURE WORK

The novelty of Cartesian Systemic Emergence lies in the fact that CSE is concerned with a formalization of the creation process of P2-SRPS *axioms*. So far, this problem has not been dealt with in modern exact sciences. However, the philosophical works of Francis Bacon [1], René Descartes [7], Peirce [16] and others express that experiences/experiments play an important role in creating the axioms. The symbiosis of axioms points out that these experiments/experiences have to be performed taking into account this particular feature of axioms. For Cognitive Science it would mean to revise all the knowledge on mental processes of the human brain in the light of a possible presence of symbiotic processes that necessarily would mean the presence of symbiotic parts in the brain. Our creative process and its creative formalization process lead us to be firmly persuaded about the presence of symbiotic processes in our brain. Researchers usually do not examine carefully their creative efforts (except for mentioning intuitive unconscious character of their productions, such as [17]). However, once we work in the framework that requires control and prevention, we no more have 'unconscious intuitions' since all the mental processes are conscious. Of course, with respect to an enormous amount of experiences gained in the teleological experimentation process, the included knowledge is not expressed verbally in its formal form but in the form of their 'rigorous' informal specifications. This may be explained by an analogy of representing local computations of Ackermann's function in the form of an on-purpose generated finite sequence of primitive recursive functions replacing the computationally intractable process (i.e., considering all the details of the considered knowledge) by a sequence of primitive recursive functions (i.e., the relevant details pointed out in the form of rigorous informal specifications).

In this paper, we aimed at pointing out the advantages of considering symbiotic pulsative recursive systems also in Cognitive Science. Even though Symbiotic Thinking and CSE are not easy to grasp for formalistic minds (as implicitly shown in [11]), it seems to us that Cognitive Science can, hopefully with our help, benefit from an intensive exploration of recognition and of construction potentials present in Symbiotic Thinking and CSE.

As for our future work on ST, describing ST in action shall need a description of the particularities of strategic aspects of PS from informal specifications in incomplete domains.

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