Resonance Thinking in Cartesian Systemic Emergence

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***Abstract*— Cartesian Systemic Emergence (CSE) is concerned with strategic aspects relative to the conception of Symbiotic Recursive Pulsative Systems intended to solve real-world problems handling control and prevention in incomplete domains. This work is performed in order to prepare fundamentals for designing automated tools that help to perform this complex task. This paper presents the most important features of one particular way of thinking present in CSE. We call it 'Resonance Thinking'. Resonance Thinking takes care of generating and handling experiments during CSE. We explain that Resonance Thinking causes the complexity of CSE to be analogous to Ackermann's function computation complexity. The work presented is related to cognitive and computation models of human creative reasoning mechanisms. Our approach brings forward several challenging questions to Cognitive Science that will be given in the paper.**

Keywords-Cartesian Systemic Emergence; Symbiotic Recursive Pulsative Systems; Resonance Thinking; cognitive models; implementation of human reasoning mechanisms; design of experiments.

I. INTRODUCTION

In [11], we have described Cartesian Systemic Emergence (CSE) as a method that handles strategic aspects of construction and particular evolutive improvement of Symbiotic Recursive Pulsative Systems (SRPS). The construction and desired improvements have to guarantee control and prevention in the system. The need for this work came out during our research on automating program synthesis from formal specifications in incomplete domains. [7] [10]. For simplicity, we refer to it as Program Synthesis (PS).The constraints imposed on this PS research required us to develop a particular systems design methodology. CSE represents our way to tackle this task. We are thus developing theoretical models and criteria representing, among others, a background for capturing and understanding the complexity of cognitive tasks involved in CSE. Resonance Thinking (RT) introduced in this paper takes care of generating and handling experiments during CSE.

In [11], we describe several facets of CSE, namely tackling underspecified information, on-purpose invention instead of manipulating a specific search space, and formulating fruitful experiments during this invention. Resonance Thinking, as a symbiotic part of CSE, possesses also these facets and describes them in a more precise way, even though a formal description has still to be worked out. CSE can be used for creating a solution for complex real-world problems, mainly those that request some kind of security handling [19], [20].

Since the illustrations of Resonance Thinking in PS or other complex real-world problems would be very cumbersome, we shall re-use here the toy example presented in [11]. The purpose of this paper is four-fold:

- describe particularities of Resonance Thinking taking place in CSE;
- illustrate this method on a toy example nevertheless dealing with a problem that many innovative researchers may have to face;
- compare the complexity of Resonance Thinking to the computation process of Ackermann's function;
- mention the main problems and challenges addressed by Resonance Thinking to various fields of Cognitive Science.

The paper is organized as follows. Section II presents fundamental notions necessary for understanding CSE and Resonance Thinking. Section III recalls the notion of CSE. Section IV develops an illustration of Resonance Thinking. Finally, Section V presents several challenges that Resonance Thinking and CSE offer to Cognitive Science.

II. FUNDAMENTAL NOTIONS

The goal of CSE is to formalize strategic aspects of human creation of *informally* specified *symbiotic systems* in *incomplete domains* following our *pulsation* model. This formalization is performed in order to prepare fundamentals for designing automated tools that help to perform this complex task. In this section, we recall four terms by which this goal is expressed and that will be also used in our presentation of Resonance Thinking, namely

- informal specification,
- symbiosis,
- incompleteness, and
- pulsation.

We shall recall also the main features of our particular handling of the well-known Ackermann's function in the construction of our pulsation model, as given in [13]. These features will be used in our description of CSE's and Resonance Thinking's complexity.

Informal specification of a system that has to be constructed is a description of this system in terms that are not yet exactly defined and that, when considered out of a particular context, may even seem absurd. These terms, in which the specification is expressed, will evolve during the system construction. In other words, depending on some

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constraints and opportunities that will arise during the construction, 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 is eliminated by the provided solution. We might say that the notions used in an informal specification are of evolutive and flexible character. Their evolution will also bring an exact specification of the context to be considered. In the framework of CSE, the notion of informal specification needs to be completed by the notions of formalized and formal specification. *Formalized specification* is an intermediary state in the progress from informal to formal specification. It consists in a collection of basic working definitions and basic tools that seem plausibly pointing out a successful completion process, even though some inventive steps may still be needed to complete the tools so as giving their final form to the working definitions. Formal specification then consists in the complete solution represented by the working system, the methodology of both functioning and system construction. These all are needed in order to be used in further evolutive improvement.

As far as *incompleteness* is concerned, from a practical point of view, we know that full reality is unknown. What we may know at a given time can be formalized by an incomplete system. From a decision point of view, it is well-known that incompleteness constitutes a large drawback [14]. Incompleteness, however, is not at all a drawback for the practical purpose of solving real-world problems that are asking for some kind of innovation. This means that, from a construction point of view, incompleteness brings a freedom for technological ingeniosity resulting in possible new technological inventions. Since an informal specification contains terms that are not exactly defined, a particular informal specification points to a context that can be represented by an incomplete environment. CSE can then be seen not only as a construction process for a system in its informally specified initial environment but also as a fruitful strategy for a progressive completion of this environment.

By *symbiosis* we understand a composition of several parts which is vitally separation-sensitive. By vital separation-sensitivity we mean that eliminating one part leads to the destruction or to a non-recoverable mutilation of the other parts and of the whole composition. This means that the widely used divide and conquer strategy is not at all suitable when creating and extending symbiotic systems. We can also say that 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. From a pragmatic point of view, symbiosis of a system is embodied by the interdependence of all notions and parts of this system. We have illustrated this, in [9], on the example of Natural Numbers (NAT) defined by Peano's axioms. NAT can be seen as the simplest existing system incarnating the main features of SRPS.

Pulsation is a model for construction and evolutive improvement of incomplete 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. This model is described in [13]. It relies on our particular handling of Ackermann's function. We shall recall now the features of its handling that will be referred to, later in the paper.

Let 'ack' be Ackermann's function defined, as in [18], by its standard definition, i.e.,

$$ack(0,n) = n+1 \quad (1)$$

$$ack(m+1,0) = ack(m,1) \quad (2)$$

$$ack(m+1,n+1) = ack(m,ack(m+1,n)). \quad (3)$$

Since ack is a non-primitive recursive function, by definition of non-primitive recursion, it is a particular composition of an infinite sequence of primitive recursive functions. In similarity to the infinite sequence which is used – in [13] – to construct Ackermann's function, the evolutive improvement (i.e., pulsation), relies on a construction of a potentially infinite sequence of systems that might, in an ideal world, 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 of incomplete theories T_0, T_1, …, T_n, $T_{n+1,}$ … such that $T_i \subset T_{i+1}, T_i \neq T_{i+1}$ (for i = 0, 1, 2, …) and such that an infinite limit of this sequence represents an ideal, complete system. Pulsation does not reduce to one particular step in this sequence. This means that pulsative systems are formalized progressively and potentially indefinitely. Pulsation is a model that does not describe how the particular systems in this sequence are constructed. This is the role of Cartesian Systemic Emergence [11].

III. Cartesian Systemic Emergence

As said above, the goal of CSE is to formalize strategic aspects of human creation of informally specified symbiotic systems in incomplete domains. In this section, we recall two paradigms that play a fundamental role in CSE and that will be referred at in Section IV. The first paradigm can be formally represented by the formula

$$\forall \text{ Problem } \exists \text{ System solves(System,Problem)}. \quad (4)$$

The second problem can be represented by the formula

$$\exists \text{ System } \forall \text{ Problem solves(System,Problem)}. \quad (5)$$

There is one main difference between these two paradigms. Namely, in (4), each problem or a class of problems related to a system can have their own solution while in (5), a unique, universal solution is looked for. The first paradigm leads to a library of particular heuristics, while the second one results in a single universal method.

CSE is concerned with the pulsative construction of a system that verifies (5). As presented in [11], the main features of CSE are as follows:

- Works with an informally specified goal.
- Handles incompleteness.
- Takes into account symbiosis and pulsation.
- Generates experiments.
- Oscillates between the paradigms (4) and (5) in order to reach a solution described by (5).

CSE has to be considered in the framework of Cartesian Intuitionism and not in the framework of Newtonian Science. In [10], we explain in more details that the main keywords of Newtonian Science are

- exactness
- formal systems and tools justified in a logical way
- methods of demonstration reduced to some axioms and rules of inference
- decision and undecidability.

In contrast to this, as pointed out in the same paper, the main keywords of Cartesian Intuitionism are

- realization and ingeniosity
- systems and tools justified in an epistemological way
- methodology of construction taking into account also 'Cartesian Intuition' (i.e., a symbiotic composition)
- handling incompleteness in a constructive way.

This means that Cartesian Intuitionism has its own, we might say 'pragmatic', notion of rigor that allows, during the research and development stages, to rely on methods and tools that do not verify the modularity criteria of Newtonian Science. This non-conformity with logical criteria and a kind of 'rigorous freedom' is justified by the work with informal notions and incompleteness.

It happens that the process of construction of informally specified symbiotic systems is very difficult to describe exactly and in its full generality. Our CSE attempts to tackle the task of its description. In [11], we present a general, even though yet informal, scheme for CSE based on the method called Constructive Matching formula construction (*CM-formula construction*) which is used in PS (introduced in [6]) for problems of type (4). We shall refer here to it as CSE-scheme.

IV. Resonance Thinking

As said above, Resonance Thinking is a method for solving problems represented by paradigm (5). It takes care of generating and handling experiments in the process of CSE so that these experiences lead to new ideas hinting at suitable symbiotic solutions of 'mismatches' among experiences themselves as well as the desired solution expressed initially by an informal specification. It is inspired by our application of Descartes' rule XII ([3], p. 39), as well as by the main precepts of his method, in the present state of our construction of a particular SRPS for PS. In his rule XII, Descartes advises: "In sum, we must make use of all the help which intellect, imagination, sense-perception, and memory can supply in order to take a distinct intuition of simple propositions, combine according to the rules things that are searched for with those that we know, as well as to discover things that have to be related to others so that we neglect no fraction of human resources." Resonance Thinking describes our understanding of Descartes' "combining, according to the rules, things that are searched for with those that we know, as well as to discover things that have to be related to others" in the framework of Cartesian Intuitionism [10].

In order to take hold of the complexity of Resonance Thinking, it is necessary to keep in mind that CSE and Resonance Thinking are designed for a systems creation which has to provide control and prevention in the resulting system. Therefore, the criterion of security is strongly involved already in the system's creation. Such a particular security follows immediately from a careful simultaneous use of the following four precepts of Descartes' method [4], p. 120:

a) "Carefully to avoid precipitate conclusions and preconceptions.
b) Divide each of the difficulties into as many parts as possible and as may be required in order to resolve them better.
c) Suppose some order even among objects that have no natural order of precedence.
d) Make enumerations so complete and so comprehensive, so we can be sure of leaving nothing out."

Note, that these four rules represent also four fundamental (symbiotic) facets of CSE in this order:

a') Pulsative Thinking, i.e., taking care of security, control and prevention [13].
b') Metamorphic Thinking, i.e., taking care of resulting epistemological equivalence between paradigm (5) and particular CSE-handling paradigm (4).
c') Symbiotic Thinking, i.e., taking care of construction of a symbiotic system.
d') Resonance Thinking, i.e., taking care of generating and handling experiments.

A description of a one part in a symbiotic composition (such as the successor function 'Suc' in NAT) is not a simple task, as one can realize while trying to give an *exact* description of the successor function (Suc) in NAT. Indeed, an exact description of Suc would imperatively require explicit references to 0, NAT, the induction principle and Peano's axioms defining the addition and multiplication. Therefore, we do not intend yet to provide here a rigorous and complete description of Resonance Thinking, as we still need to describe in a future work, more in details, Metamorphic Thinking (MT) and Symbiotic Thinking (ST). On the other hand, CSE and Resonance Thinking handle informally specified notions (and thus incompleteness). This means that, it is only natural that procedures and notions of CSE come out through progressive evolution from informal specifications to formalized specifications and then to formal specifications. In this paper, we shall therefore limit ourselves to an illustration of the goal of Resonance Thinking and the basic procedures it relies upon.

We shall present Resonance thinking and its basic notions with the help of a toy example used, in [11], for description of CSE. In comparison to examples provided by PS framework, this example is simpler and could illustrate many other scientific fields than PS-research does. The example problem presented here concerns conveying a new original scientific knowledge in such a way that its essential content and creative potential are preserved by the next generations. This is not a trivial problem as already pointed out in the past [1] [4]. Our experience confirms that, for new knowledge that concerns creation and extension of symbiotic recursive systems, this problem remains relevant until now.

A. *Specification of a toy example*

In this section we present our example illustrating CSE and Resonance Thinking.

Let us suppose that René is a founder of a novel scientific theory with a high pulsative potential. Referring back to the bad founders' experience in the past, he needs to ask himself: "How to build some 'works' able to convey the full complexity of my new theory while simultaneously preventing a degradation of its pulsative potential?" In a more formal way, René must solve a problem informally specified as:

$$\exists\text{works } \forall\text{disciple conveys(René, works) \&} \\ \text{conveys(works,disciple)} \Rightarrow \qquad (6) \\ \text{essential\_of(René) = essential\_of(disciple)}$$

Note that this problem has the same logical structure as the second paradigm presented in the form (5). Specification (6) is an informal specification. As said above, this means that the notions that appear in (6) are not defined in a rigorous way. They are only specified in an informal way in terms of some non-formal criteria (i.e., a kind of underspecified constraints). This means that a solution 'works' for (6) has to emerge simultaneously with suitable formalizations (thus, the final definitions) of notions that occur in (6). In the following, we shall denote by D_t the set of (initially underspecified) sentences specifying 'to convey' and by D_e the set of (initially underspecified) sentences specifying 'essential_of'. These sets evolve in the process of CSE and Resonance Thinking towards a more rigorous final form. For simplicity of presentation, we do not involve such an evolution in our notation.

In [11], we mention that, in order to solve (6), there is a particular switch to a framework of experiments described by the formula

$$\forall\text{disciple } \exists\text{works conveys(René, works) \&} \\ \text{conveys(works,disciple)} \Rightarrow \qquad (7) \\ \text{essential\_of(René) = essential\_of(disciple)}$$

This formula represents paradigm (4). Above, we have explained that there is a difference between solving (4) and (5), and this obviously applies to their instances (6) and (7). In general, in order to be fruitful and justified, a switch from (5) to (4) has to rely on what we call Metamorphic Thinking. Roughly speaking, Metamorphic Thinking (MT) takes a care of a rigorous, epistemologically and pragmatically justified transformation of paradigm (5) into the context of paradigm (4). Our paper [11] gives its illustration. A more detailed description of MT is presently under development.

In other words, MT provides a switch from (6) to (7) that is useful in order to generate experiments leading, within the framework of (7), to some hints and inspiration for solving (6). These hints and inspirations represent temporary (see precept (a)) underspecified constraints that enlarge the already existing set of underspecified constraints. In order to generate such inspiring experiments, while considering (7), from the set of all disciples, we chose a finite number of disciples $d_0, d_1, \ldots, d_n$ that seem highly different so that each of them seems to need a different 'works'. Note that this step implicitly embodies the above precept (b). We shall call *representatives* these disciples. In other words, our experience shows us that challenging experiments are needed to obtain some inspirations contributing to a solution of (6) in the framework of paradigm (5). Note that we order these disciples in a numbered sequence just for the presentation purposes. This will be useful when describing recursive procedures that handle this finite set of disciples.

Very roughly speaking, in order to solve a problem represented by paradigm (5), it might seem possible to replace MT from paradigm (5) to (4) by a symbiotic composition of a set of solutions for carefully chosen representatives of universally quantified elements of this paradigm. A drawback of such a description lies in considering a lone symbiotic operation (i.e., one action), while Resonance Thinking, through precepts (a), (b), (c) and (d) requires performing a great number of interdependent symbiotic compositions, as will be described below.

Recall that the two operators 'conveys' and 'essential_of' are here specified informally only by some set of sentences that represent informal descriptions (i.e., underspecified constraints) relative to these notions. Thus, we shall replace these notions by their informal descriptions. Above, we have denoted by D_t the set of sentences specifying 'to convey' and by D_e the set of sentences specifying 'essence_of'. Therefore, (7) writes as

$$\forall\text{disciple } \exists\text{works } \{ D_t(\text{René, works}) \,\& \\ D_t(\text{works,disciple}) \Rightarrow D_e(\text{René}) = D_e(\text{disciple}) \} \quad (8)$$

Let us consider (8) for each particular d_i, i.e.,

$$\exists\text{works } \{ D_t(\text{René, works}) \\ \& \, D_t(\text{works}, d_i) \Rightarrow D_e(\text{René}) = D_e(d_i) \} \qquad (9)$$

In [11], we show that a solution for (9) can be found for each d_i by following CSE-scheme and oscillating between paradigms (4) and (5). This solution consists of a concrete value w_i for 'works' and of less informal descriptors $D_{t,i}$ and $D_{e,i}$. We shall note $Sol_i = \{ w_i, D_{t,i}, D_{e,i} \}$. Due to a careful oscillation between paradigms (4) and (5) the descriptors $D_{t,i}$ and $D_{e,i}$, w_i refine 'works' and the operators 'to convey' and 'essential_of' in (6). These resulting refinements 'resonate' with the framework of paradigm (5). By their resonating we mean that, during the experimentation process, we feel that they might, probably after some 'judicious adaptations', be applied also to other instances of 'disciple'.

B. *Resonance Thinking*

Resonance Thinking relies heavily on what Merriam-Webster Dictionary considers as resonance: a quality that makes something personally meaningful or important to someone. Resonance Thinking thus involves the ability to create and explore personally meaningful or important relations in the process of generating and handling experiments.

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We are going to describe it in the framework of René's example.

At this stage, we suppose that (9) for d_0 is already solved following the CSE-scheme. Sol_0 represents thus a 'temporary' solution for d_0. By 'temporary' we mean that this solution will still have to be approved or modified by Resonance Thinking. Procedurally, the part of generating experiences of Resonance Thinking is based on two procedures for which we cannot yet provide a detailed description (thus, making explicit also 'handling experiments' part of RT), as they rely also on other symbiotic facets of CSE not introduced yet (namely, MT and ST mentioned above). We shall therefore concentrate on explaining the role of these procedures. The first procedure will be called *topological symbiosis* (noted *ts*) and it is also a primitive operation for the second procedure. The second procedure is called *complementary topological symbiosis* (noted *cts*). Both these procedures require creativity in developing symbiotic systems. In this paper, we describe the way these procedures work: they are therefore to be handled, for the time being, by a creative human person. The following description of the role of *ts* and *cts* illustrate some of the challenges that *ts* and *cts* have to tackle.

1) On symbiosis in Resonance Thinking

We need to point out here two particular features of *ts*. The first one concerns the character of possible "mutilations" performed by *ts* and the second one concerns its goal.

In [8], we present an example of a pictorial symbiosis of two different women. One woman is young, the other is old. The resulting symbiosis is a face that can be seen simultaneously as a young and an old woman. The original two pictures of women have to be 'mutilated' so that the resulting symbiotic picture is convincing. For instance, an eye of old woman and an ear of young woman overlap in the symbiotic picture. As for the opposite ages of the women on the initial pictures, they are 'merged', since the symbiotic picture is at the same 'old' and 'young'.

In [9], we used the example of Peano's axioms that are (also) symbiotic since, by deleting one of its axioms, the reduced set of axioms leads also to other interpretation structures (such as, for instance, the set of Perfect Women in [8]). This example exhibits an explicit degradation due to the presence of a set of notions and constraints that obviously became underspecified when one of Peano's axioms is deleted. This shows that, at first glance, systemic symbiosis manifests itself not so much as 'merging' contradictory facets of the considered system (as 'merging' two opposites, namely young and old in the above mentioned pictorial symbiosis), but as constructing an emergent vitally separation-sensitive interdependence (i.e., symbiosis) of parts of the system. However, a detailed perception shows that this vitally separation-sensitive interdependence means 'merging' relationships that are usually contradictory, for instance, '*p* depends on *q*' and '*q* depends on *p*'.

2) On generating experiments in Resonance Thinking

We are going to describe *ts* and *cts* in the framework of René's example. At this stage, we suppose that (9) for d_0 is already solved following the CSE-scheme providing the solution Sol_0 for d_0. Sol_0 represents a 'temporary' solution for d_0. By 'temporary' we mean that this solution will still have to be approved or modified by RT. Similarly, for other disciples d_1, …, d_n, we will obtain Sol_1, Sol_2 and so on. We assume here that the solutions are obtained in a particular 'linear' way, one after another. This 'linear' way looks as follows.

Once Sol_0 is constructed, a 'temporary' solution Sol_1 for d_1 is constructed ('temporary' in the same way as Sol_0 is a 'temporary' solution for d_0). Note that both these constructions may lead to new experiences and thus, *they modify the initial environment* by refining the informal notions of our definition (6) of our problem. For the sake of simplicity, we do not describe explicitly below this evolution of environment, though we take it into account by calling it a 'feedback' when we use it.

Now, suppose that we solved the problem for the first disciple. Before starting solving the problem for the next one, we try to take into account the informal notions present in (6). This try amounts to an attempt to 'merge' the solutions Sol_0 and Sol_1 using topological symbiosis *ts*, i.e., we try to achieve their symbiotic composition that resonates (as explained in Section 4.A) with the informal specification (6). We shall denote this process by $ts(Sol_0,Sol_1)$.

If solving $ts(S_0,S_1)$ fails, i.e., we cannot find relevant refinements, we keep in mind the feedback obtained while constructing Sol_0 and Sol_1, as well as the failure reasons of $ts(S_0,S_1)$. This failed step will have to be redone later while relying on some inspirations that may rise while finding the solutions for the next disciples. If this process fails, the problem will have to be considered as a challenge for one of the next pulsation steps.

If the process $ts(Sol_0,Sol_1)$ succeeds, both solutions are temporarily approved. Then, keeping in mind all the feedback obtained, a solution of (9) for d_2 is constructed. One might suppose that this process may continue linearly as suggested by its beginning, as we just have seen. However, recall that we work in an environment that requires control and prevention. Therefore, in this environment, we rely strongly on the above four precepts. This means that generating complementary experiments for topological symbiosis of solutions constructed is necessary. We call *complementary topological symbiosis* (noted *cts*) this procedure for generating new experiments.

Roughly speaking, *cts* is a particular generation process (defined with help of *ts*) for creating experiments. The goal of these complementary experiments is to provide inspirations for further refinement of underspecified notions and constraints. Similarly to the computation of ack (see [12]), in the process of generating experiments (via *ts*) for Sol_m and Sol_n, i.e., while 'computing' $cts(Sol_m,Sol_n)$, the operation $ts(Sol_i,Sol_j)$ for other solutions Sol_i and Sol_j is performed several times.

Let us denote by $ts_1(Sol_i,Sol_j)$ the solution of the first computation, by $ts_2(Sol_i,Sol_j)$ for the second computation, and so on. It is important to point out that $ts_p(Sol_i,Sol_j)$ and $ts_q(Sol_i,Sol_j)$ in this sequence of computations may carry two different feedbacks. Indeed, each inner step of *cts* (i.e., evaluating $cts(Sol_m,Sol_n)$), may bring new refinements, constraints as well as it may point out to missing knowledge or second-order notions and procedures. The procedures *ts* and *cts* have to insure that not only reasonable and achievable solutions are obtained but that a possibility of future evolutions are guaranteed while properly handling prevention and control.

Recall that *ts* and *cts* are, in our case, presently performed by a human mind. This means that human mind can rely on relevant creativity in order to decrease the number of repetitions. In consequence, even though *ts* and *cts* are not simple, CSE and Resonance Thinking are not overwhelming tasks for human performers. However, they may be overwhelming for a human observer even in this simplified form. This is why we believe that further research is necessary to give a reasonable formula for performing *cts* by machine.

V. DISCUSSION/RELATED WORK

Scientific creation, as a particular human invention [15], becomes a highly economically interesting topic when it can be turned into an implementable science. CSE does try to build an implementable theory of SRPS scientific creation. Since it is based on our relatively successful experience in creating a methodology for PS, the four fundamental facets of CSE bring several stimulating challenges to Cognitive Science (CS). Some of them have been presented in [11]. In this paper we would like to mention two more challenges. They concern frame problem [2] and conceptual blending [5].

Bermudez' work, as cited above, seems to imply that CS is somewhat wary of non-modular processing. One of the reasons is that non-modular processing very quickly meets frame problem-like difficulties. We have seen that, during Resonance Thinking, the human brain is rather at ease with the identifications needed to handle the frame-problem. Why it is so? Is it because there is a particular kind of internal representation human mind is able to construct? Alternately, is it because our mind includes mechanisms that are presently out of the scope of the current modular approach to our mind architecture [2]? Moreover, performing CSE includes a symbiosis of form, a meaning, a representation formalism, mechanisms and, importantly, reaching a human agreement via conceptual coherence [16] and real-world exploitation. Does it mean that a modular approach to mind architecture should be revised? Could it be possible that some kind of symbiotic approach might be better suited even though it is more complex?

Besides, we have tried to find some concepts of CS that resonate with CSE-thinking. We have found some similarities between Resonance Thinking and Conceptual Blending (CB) as presented in [5]. On a high-level of abstraction, RT and CB seem similar, since they are both concerned with construction of meaning and they both involve 'merging'. Of course, they also show some differences at this high-level because RT is consciously performed, while CB is considered as taking place outside consciousness and is not available to introspection (as in [5], p. 33). We believe that this unconscious feature of CB disappears if people work in domains where rigor, justification and reproducibility of results are essential. Incidentally, let us point out that Fauconnier and Turner's illustrations, in [5], do not fulfill these stipulations.

At a lower-level, RT seems to us more complex than CB. Let us mention several features of RT that contrast CB.

- CB is highly nondeterministic while, in RT, the solution is specified in advance, even-though informally. Thus, RT performs what could be called a 'goal-oriented symbiosis'. While handling the generated experiments, RT focuses on what resonates as contributing to a universal solution, as in René's example, 'works' in (6).
- RT involves solving underspecified constraints due to the presence of incompleteness and an informal specification.
- RT not only handles a given data input (experiments) but it also generates complementary data (experiments).
- CB usually works with two mental spaces. RT, via topological symbiosis, works with three inputs (two experiments and one goal) and the solutions obtained are temporary until other experiments confirm the output.
- Fauconnier and Turner [5], in relation with CB, claim that researchers are unaware of how they are thinking. RT is a description of our way of thinking relevant to creation of SRPS.
- CB is performed on mental spaces, i.e., small conceptual pockets constructed for purposes of local understanding and action ([5], p. 40). In RT, there are no small conceptual packets since global understanding is required even in considerations that may seem local.
- In the case of CB, the effects of some unconscious imaginative work are captured by consciousness, but the operations that produce it are not ([5], p. 58). As said above, RT (and CSE) is a description of our way of thinking that is relevant to SRPS creation. This means that we are consciously aware of the informal specifications of the operations performed by our mind. Presently, our goal is not to apprehend all the conscious details of the operations performed by RT and CSE. Our present goal is to specify what enters into the 'game' of RT (and CSE) and what the 'winning strategies' are in order to conceive all the rules of 'the full game' of CSE. In other words, presently, we aim to develop a 'prosthesis' that can be implemented and used during CSE. We are convinced that apprehending human operations first by relevant informal specifications is half way to a reasonable implementable solution.

We can also compare 'mismatch-based learning' presented in [21] to our 'mismatch-based creativity' in the following sense. Any proof performed in an incomplete domain always faces a possibility of leading to a failure. This means that we are bound to provide means of recovery from these temporary failures or, alternatively, strategies making use of the failure itself – which is a way to recover from such a failure by including the failure cases inside the domain. An

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example of the last kind of recovery has been provided by Grossberg who, in [21], introduces a procedure including ‘mismatch-based learning’ cases in order to enable a rapid adaptation to changing bodily parameters relative to the posterior parietal cortex. Our approach, however, relies on a creative recovery more than a learning one, as explained above.

VI. Conclusion

It is largely accepted that inspiration seems to take place anytime, such as while walking (e.g., Poincaré’s case), showering or during a pause playing the violin (e.g., Einstein’s case). It is usually also accepted that some sort of unconscious incubation precedes this inspiration. Since we differentiate ‘unconscious’ and ‘non-verbal’, this does not take place during RT. Furthermore, contrary to Popper’s opinion [17] that “there is no such a thing as a logical method of having new ideas, or a logical reconstruction of this process,” RT is a systemic method for generating new and relevant ideas. Of course, its ‘logical reconstruction’ is not trivial, as is illustrated by this paper. CSE, CSE-scheme, RT, Symbiotic Thinking and Metamorphic Thinking nevertheless seem to be a good start for a ‘Cartesian reconstruction’ of this process. Thus, we believe that, even in its presently incomplete version, CSE brings forward thinking mechanisms that are essential for exploration, creation of possibilities, anticipation, resonance, blending, on-purpose creating of informally specified tools, invention, discovery, and so on.

We are aware that our description of the cognitive tasks involved in CSE does not provide a clear idea whether it is possible (or reasonable) to find a way to break down the cognitive tasks that are performed into more determinate tasks. We describe what humans do or what they have to do without specifying how these tasks are performed by our brain. We thus believe that research on these topics in the field of CSE in particular and its comparison with scientific creativity in general (i.e., a comparison with scientists’ creative thinking in several scientific domains) might bring new conceptual and procedural switches not only in Computer and Cognitive Sciences, but also in other human activities.

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