Possibilities of modeling the creative part of engineering design process using the synergetic approach

Dmitri Loginov

***Abstract*—**In this paper the problem of modeling the creative part of the engineering design process has been analyzed from the synergetics perspective. The analysis possessed from a general point of view. The characteristics of the creative tasks of the engineering design have been defined and novel notion of the Autonomous Design System (ADS) has been introduced. ADS is considered as an advanced CAD system that has Artificial Intelligence (AI) functionality and particularly the functionality to deal with creative components of the engineering design process. A couple of cybernetic models which may be further optimized by the methods of synergetics were proposed. The presented discussion forms theoretical foundations and philosophical motivation for an ongoing research in this field. This work constitutes the introduction to the extension of the author's original research in the field of CAD systems' optimization.

***Keywords*—** Self-organization, Engineering design, Synergetics, Artificial intelligence, Complex systems.

I. Introduction

Engineering design can be viewed as an articulate process composed of phases, where each phase represents a combinatorial action on the parts the composite object is consisted of. To realize an object meeting the desired market requirements, engineering designers have to deal at the same time with different kinds of knowledge about objects or, ontological knowledge (which is often represented in a declarative form), and "dynamic" knowledge about processes (which is often represented in "procedural terms") [1].

Synergetics can be considered as one of the modern, most promising research programs. It is oriented towards the search for common patterns of evolution and self-organization of complex systems of any kind, regardless of the concrete nature of their elements or subsystems.

These parts of design process that are numerically analyzable could be modeled numerically. The numeric model could then be further improved and optimized. We can use all the benefits and achievements of the digital revolution, including Artificial Intelligence (AI), to automate the process of engineering design.

A. Creative part of engineering design

On the other hand, the design process consists of the "creative" part that is not numerically describable by traditional numerical algorithms, at least not yet. As today's traditional CAD (Computer Aided Design) systems are based on numerical (digital) computational machines (i.e. personal computers), there are no ready standard solutions to automate these creative parts of the design process. Note that "routine" parts of the engineering design process could be modeled, divided in parts and automated relatively simply, and there are a lot of examples on the market today.

On the contrary, there is only one stage in the true model of the creative process. At the simplest level, creativity is the act of being and doing folded into a state of flow called life. We naturally spend all of our time in a state of flow, despite claims in the popular press to the contrary. Even when we are analyzing a problem, we are *doing* something, and employing tools of some sort. We simultaneously embrace a rapidly evolving picture of what we want to do that unfolds just before we do it. What the popular press describes as a state of flow occurs when the execution of the creative process becomes jubilant, and consequently high performance.

We divide the creative process into pieces in an effort to understand and picture the complexity of the entire process. But let us not fall into the trap of believing that we actually execute the pieces in some sort of lock step fashion. It is convenient and instructive to perceive that creativity has certain stages and that we can all emotionally, physically and mentally relate to these stages, but to hold any model of the creative process as a precise description of creativity, and to force others to adhere strictly to its application is foolish. Stuart Kauffman uses an expression to describe the difficulty of modeling any living system: "the algorithm is incompressible." In other words, there is no shorter method, routine or program to describe life or living systems than life or the living system itself. Models are representations of reality but they are not the reality itself. There is no algorithm or equation that we can force creativity into that is shorter than the creative act itself [2]. However, there is a hope that we can still approximate the model to its representation by introducing (and using) the emergent AI technology, its tools and algorithms.

B. Synergetics and self-organization

Synergetics (Greek: "working together") is an interdisciplinary field of research originated by Hermann Haken in 1969. Synergetics deals with material or immaterial systems, composed of, in general, many individual parts. It focuses its attention on the spontaneous, i.e. self-organized emergence of new qualities which may be structures, processes or functions. The basic question dealt with by Synergetics is: are there general principles of self-organization irrespective of the nature of the individual parts of a system? In spite of the great variety of the individual parts, which may be atoms, molecules, neurons (nerve cells), up to individuals in a society, this question could be answered in the positive for large classes of systems, provided attention is focused on qualitative changes on macroscopic scales. Here "macroscopic scales" means spatial and temporal scales that are large compared to those of the elements. "Working together" may take place between parts of a system, between systems or even between scientific disciplines. See e.g. [3], [4] for further reading.

A simple example of self-organization is a case of a fluid heated from below which may form patterns in the form of hexagons or rolls based in an upwelling of the fluid (Fig. 1).

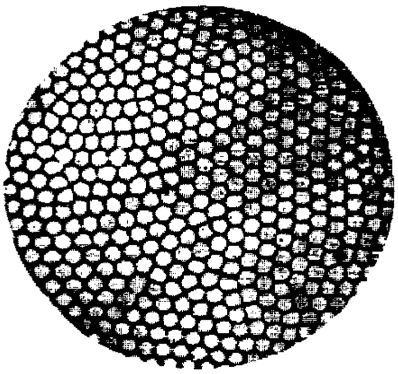

Fig. 1 Top view of a liquid in a circular vessel heated from below

When the temperature gradient exceeds a critical value, hexagonal cells are formed. In the middle of each cell the liquid rises, sinking back down to the edges of the hexagon. Further examples are provided in physics by the production of coherent light of lasers, in chemistry by the macroscopic rings or spirals formed in chemical reactions and in biology by morphogenesis during the grows of plants and animals.

The sunflower head, for instance, is composed of two counter rotating spirals, which must hit under a quite specific angle (Fig. 2).

Fig. 2 The sunflower head is composed of two counter rotating spirals

The reason for this is not yet fully understood. Another example is in behavioral patterns which may range from the gaits of horses to the specific movements of human beings. In all of these cases the systems acquire their structures as a result of rather unspecific changes of their environment, for instance when the fluid is heated more strongly or when the concentration of a chemical is changed and so on. In other words, the structures evolving in the system are not prescribed in a specific manner from the outside. More precisely, the system forms its new structure by self-organization.

II. Problem Formulation and Analysis

The creative parts of the design process are characterized by the higher intelligence needed to deal with them. Therefore, if we want to model that part of engineering design we need far more powerful AI technologies then those existing today.

It could not be even possible to model/automate these creative components by means of today's computers. Maybe some new revolutionary technology is needed to do that. However, there is a belief that some of these components still may be approximated (to some degree) by mathematical methods that are readily available now (by their improvement) or by the newest methods that have emerged recently, or those, still under development at the moment. The AI tools and technologies in cooperation with synergetics, for instance, may help us to achieve that goal.

Synergetics (in the meaning of H. Haken's school of thought) provides mathematical tools to cope with the self-organization phenomenon. These tools are based on the combination of the differential equations theory and the stochastic modeling. The principles of synergetics can be used in a great variety of scientific disciplines ranging from the theoretical physics to musical [5] and social sciences. Let us look first at the synergetics from the general, epistemological point of view.

Synergetics reflects the surrounding natural systems in a sense of soft or coherent action principle. The natural phenomena develop along the evolutionary paths according to evolutionary principles. There are no hard or external actions which can successfully drive (manage) the complex natural system in its development pathway. From that we may learn how to arrange our activities in order to achieve optimal results. It turns out that managing influence must not be energetic, but rightly topologically organized according to the general and universal laws of self-organization. There must be certain organization of actions. It is the topological configuration, the symmetric "architecture" that is important, not the intensity of the influence. Synergetics defines how it is possible to multiply reduce time and required efforts to generate, by a resonant influence, the desirable and, what is no less important, feasible structures in a complex system. These principles are equally applicable to the case of modeling the complex parts of engineering design process.

Leo Näpinen, for example, stresses the importance of participative constructive activity as follows [6]. "The cosmos is filled with the creativity of the process of endless transformations, and human creativity derives from the creativity of the cosmos itself. Human constructive activity is justified indeed — but not a dominative construction. Instead, it has to be participative construction."

A. Overview of the related research

The question is not whether we could model the creative component on today's computers using common, traditional computational methods, because the simple and obvious answer to this is that we could not. The question is rather could we invent some new computational methods that allow to model the creative components of the design process. According to [7] it is possible by investigating the social-biological functionality of the human species. The authors note that deeper computational studies of biological and cultural phenomena are affecting our understanding of many aspects of computing itself and are altering the way in which we perceive computing proper.

The authors propose to model human intelligence by modeling individuals in a social context, interacting with each other. The important point is that while interacting they have to change their thinking process not just the content. The authors oppose that to the software agents' systems, which, according to them, are only capable of exchanging information while their own state persists unalterable. We argue here against the view of software agents' paradigm, since agents may have dynamic structures, which are capable of learning and improving their functionality over time (they could be linked to artificial neural network, for instance, or to other AI systems [8], they may be a part of Complex Adaptive System (CAS), as described in [9]). The social behavior greatly increases the ability of organisms to adapt. Minds arise from interactions with other minds.

The interesting insight into the problem gives Jorma Tuomaala [10], who considers creativity as the product of humans' subconscious mind and the intuition. He then proposes the process of formalization of the creativity based on intuition and combination of conscious and subconscious mind. The author is not naming that explicitly self-organization, but it is obvious that his methods of "capturing" creativity are tightly bound up with the notion of self-organization and synergetics (theory of self-organization).

In his book he attempts to handle the intuitive process and the possibilities of its controlled use based on his own experiences as a mechanical engineering designer. He examines in what ways one might use one's subconscious and conscious mind together in engineer's design work. He notes that this study is completely fictitious as far as subconscious mind is concerned. Nevertheless, he has tried to develop a model of it that may increase the understanding of the function and may even be useful in practice. He has also tried to expand the discussion to the area of literature and performing art, because he sees engineering design, as well, as a deeply human activity giving one all the possibilities to grow as a person (such approach is also articulated in self-organization paradigm where someone creates arts i.e. "finds out" order from chaos). He has tried, also, to build a generally applicable method of intuitive creative work. According to J. Tuomaala creativity is needed in the creation of everything new. He explains that the ideas produced intuitively seem to be, despite all arguments, usually of the best quality. This arouses the question: should one mainly seek to use intuition along with the systematics in (mechanical) engineering and

a) Can one then still define the time needed to find solution?

b) Can one consider the intuitive solution as an optimum?

c) Does the time used for solving the problem affect the quality?

d) Is it possible to lead the intuitive process?

And at last, we may ask the question, if the intuition seems to be a useful instrument in creative engineering design, is it possible to model it using some computational algorithm?

Another attempt to formalize the creative part of the design process was done by MG Taylor Corporation and brought/explained by Bryan Coffman in 1996, see [2]. Very interestingly, MG Taylor Corporation seems to deal with creative design formalization since 1982, but even today there are no working examples of an autonomous engineering design system created (i.e. system that is capable of modeling the creative part as well), although there were attempts to create a conceptual framework and general methodology to aid the design of complex adaptive systems using the principles of self-organization [9].

The ongoing research in AI domain and in the field of general technology shows that traditional methods of solving engineering problems based on formal logic and systematical approach shifts toward the new unrevealed, presently undocumented features of human mind and intelligence (more closely to the characteristics of self-organization?). There are neural networks, which try to copy the functionality of biological brain cells – neurons, fuzzy logic and modeling (for a contemporary research on fuzzy dynamic systems see e.g. [11]), expert systems, evolutionary programming/computing, knowledge-based systems, swarm and genetic algorithms and so on. In that sense we can compare this to the paradigm shifts that occurred in 20th century when the new age science transformed from its classical period (Galileo-Newton physics) out to non-classical (quantum mechanics, static laws and systems) and post non-classical (open non-linear systems etc.) forms.

B. Synergetic modeling

The routine parts (numerically describable) of the engineering design process could be successfully modeled with the help of cybernetics. It is really the art of combinatorial manipulation and constructing (constructive rationality) to fulfill the goal, using the already known or novice technology, IT in this case. As it is based on cybernetics, it falls down to organizational theories, contrary to self-organization paradigm, and therefore is not the subject of interest of this paper.

Let us take a look at the notions of organization and self-organization from the concept point of view. The concept of organization denotes the process that leads to the rise of goal-oriented structures due to conscious human goal-directed action or some external ordering influence, and the concept of self-organization would denote the process that leads to the rise of goal-oriented structures beyond conscious human goal directed action or some external ordering influence. Although the term “self-organization” is widely used (and more appropriate) in the field of synergetics, it has been utilized in cybernetics as well. In cybernetics, however, it has different meaning (from the philosophical point of view). In cybernetics and systems engineering self-organization is understood as an effect of an external ordering factor (e.g. self-organizing map in [12]). In synergetics self-organization is understood as the rise of harmonious behavior distinguished from man's intervention and from external (with regard to the system) ordering factors. External factors (e.g. strong non-equilibrium) are indispensable for self-organization, but only as conditions, not as ordering forces.

Hopefully, it is possible to imitate the creativity (at least to some degree) by means of synergetic modeling. Could we model the creative part of the (engineering) design process as well? To answer this question we must analyze the synergetic approach and compare it with traditional information technology modeling instruments e.g. with cybernetics.

In cybernetics as well as in synergetics the objective processes are modeled in order to control them. The cybernetic models make it possible for man to strive for the desirable results using the program created by him. The synergetic models take into account that the programs form in the course of self-organization [13].

All exact sciences (and also the traditional scientific cognition) are model-based. They are exact only within that model. Therefore it is not possible to explore/predict/study adequately the real world by means of “exact” sciences by definition. We can use exact sciences to explore models. CAD systems, ADS (Autonomous Design System, ADS is considered to be a further development of a conventional CAD system, which takes into account the creative component of the design process) frameworks are examples of design systems’ models. Both cybernetics and synergetics are exact sciences as well. So we can use these disciplines only for the development and research of models of the underlying real world’s phenomena and not for the investigation of the real world itself. It must be underlined that in exact sciences the approach to the interaction between organization (management) and self-organization does not go (and due to the specificity of exact sciences must not go) farther from certain boundaries.

The limits mean that exact sciences in their models of influence upon self-organization give only such recommendations according to which the future state of an object of management is given from the outside. Exact sciences do not make any contribution to the opening of the creative potential of the elements of the system [13]. So we cannot use standalone synergetic methods (a kind of exact science) to explore the creative potential of the system (and self-organization). As the synergetics is exact science and is based on mathematics, it has known limitations in its capability to explore the real world. But still we can use it to create the better models of the real life systems, not to understand these systems completely. On the other hand, building more adequate models of the environment leads to a better understanding of the environment itself. And, therefore, may lead us to a new level of understanding, to help us form a new paradigm and from within it - to model even more precisely, closely to the real world.

Synergetics better than cybernetics models the processes of the real world which is ultimately the self-organizing system. So we can use principles of synergetics in conjunction with traditional computing technology to model some aspects of the real systems. It is worth showing how creativity is understood in synergetics. The meaning of the word creative is the unpredictability and unavoidability of the unknown. The creative chaos is the field of unknown and unpredictable chances. The meaning of the word is closely related to such concepts as non-equilibrium condition and conditions close to equilibrium.

Synergetics accentuates also one necessary condition of self-organization: the order arises from chaos only under the condition of *strong non-equilibrium*. It is necessary to distinguish strictly chaos under the conditions close to equilibrium (in which, generally speaking, self-organized structures can only decompose) from chaos under the strongly non-equilibrium conditions (in which composing of structures through self-organization can take place) [13]. The former type of chaos is non-creative, the latter is creative.

In engineering design process theory the meaning of the words “creative” (and “creativity”) is slightly different. Here the word “creative” denotes a non-routine part of the design process. Contrary to the routine procedures where inputs and outputs of the system are known or predictable, the creative part of the process deals with output data that is mainly unknown, although the field of possibilities (possible outputs) is generally defined. This is true in ordinary design scenarios where the ultimate goal of the design procedure is known.

When the output data of the system is completely undefined and unknown, then we are dealing with the system that generates some new design information (i.e. invention mechanism). Note, that the input data in majority of cases is defined (both in ordinary design scenarios and in invention apparatus). The modeling of the technical invention processes is even more complicated (if not impossible) than imitating the creative part of the conventional design process (i.e. the process where the field of the possibilities of the output information is defined). There is a hope that using the methods of synergetics and the philosophy of self-organizing systems we can try to address the problems of modeling creative design in a more precise and better manner. The new science which accepts creativity based on chance and irreversibility in nature, and considers the fundamental indeterminacy of the whole history of nature and of human society should evolve to acknowledge the potential of this approach.

Basically, we can consider a model as an idealized version of the real system. The model is always a simpler and more primitive than the real system. The traditional tool for creating engineering design models nowadays is a Computer Aided Design (CAD) system. For a creation of a new CAD system we use CAD programming. Thus, CAD programming is essentially construction of the model (computer program) for the model (CAD application) of a model (engineering design, project) of the system (e.g. engineering installation). Such models' cascading occurs e.g. in a case when we are programming under some existing CAD platform, let's say under AutoCAD®. On this level of abstraction the model itself is very precise (it is nested into surrounding model etc.) and perfectly describable by mathematics.

The aim is to try to add to this model the properties/specifications of the self-organizing systems' behaviors. The author does not really think that the model will be capable of substituting the engineer completely in the process of producing creative design. But there is a hope that the model built in the spirit of synergetics could facilitate the emergence of the elements of the creativity in engineering design in which the human participates as well. It is likely that these models in cooperation with the operator (engineer) can function more effectively in creating new designs. Moreover, the engineer and the model in conjunction both virtually constitute a self-organizing system and the number of degrees of freedom of that resulted system is bigger than in each of its separate part. Thus, the probability of emergence of interesting and usable design scenarios is larger. It must be stressed here that we do not know whether the useful design cases ever emerge as a result of using the synergetic model. It is impossible to specify when and what kind of outputs from the model will be created. This would be a kind of system with a rather probabilistic behavior, therefore, in theory it could even downgrade (to some degree) the developments of the design process, but, nevertheless, even in that case it still will be operating according to the principles of self-organization. And maybe, who knows, the wrong output (as it seems at present time) will be considered over time quite a better one. The big question is how to compound such a system that it could be, so to say, maximum self-organizing, because we still have to construct it, i.e. the system does not emerge as a result of self-organization in principle. Maybe the wiser behavior would be the passive one – not to construct, but be inactive, wait till the systems will arise by themselves? Or just create some very simple systems with minimum "dominative construction" attributes and let the general outer self-organizing world finish the model according to its intrinsic implicit laws (as we know from synergetics, it seems that just the simpler laws drive complicated phenomena)?

Here is a quote from K.Popper's book "All Life is Problem Solving" [14], where he emphasizes the value of free opinion's formation, which in conjunction with simple clear language (analogy to simple "laws" that drive complex phenomena?) may be considered as characteristics of self-organization (in social context). "Why does simplicity of language matter so much to Enlightenment thinkers? Because the true Enlightenment thinker, the true rationalist, never wants to talk anyone into anything. No, he does not even want to convince: all the time he is aware that he may be wrong. Above all, he values the intellectual independence of others too highly to want to convince them of important matters. He would much rather invite contradiction, preferably in the form of rational disciplined criticism. He seeks not to convince but to arouse—to challenge others to form free opinions. Free opinion formation is precious to him: not only because this brings us all closer to the truth, but also because he respects free opinion formation as such. He respects it even when he considers the opinion so formed to be fundamentally wrong. "

It is possible to possess experiments with some candidate synergetic models in order to select the more appropriate one (we must remember, however, that in experimental situations, the determinants of the organization or process are contingent on the subject i.e. the experimenter; for a detailed description of the philosophical interpretation of humans' constructive activity (based on Aristotle's four causes that in unity form the philosophical category of self-organization) see e.g. [15]). But again, what are the criteria for the selection and are these criteria adequate enough? Self-organization is impossible to describe adequately in details, so how it is possible to define adequately its characteristics for the selection criteria?

III. Problem Solution

In this section a short overview of the cybernetic models, which are suitable to combine with synergetic methods, is given. Note that these models are novice and they are under research right now. Initially they were intended to use as a standalone frameworks for a creative components of the Autonomous Design System (ADS). ADS is defined as an advance CAD system, which has AI functionality and *particularly the functionality to solve the creative tasks* of the engineering design process. ADS is opposed to the conventional CAD systems, (see e.g. [16]) which normally automate routine parts of the design process and generally have no AI capabilities.

A. General remarks

The properties of self-organizing systems in general could be discovered (if ever) using the methods of historical cognition (although in relatively small isolated groups/systems it is possible to use methods of classical exact sciences for that purpose). These methods are closely connected with the notion of time. The analysis of the historical phenomena is not possible without any knowledge on their past, as they develop in the process of irreversible evolution. Thus the future is unknown and unpredictable.

From the philosophical point of view it seems that the hypothetical-deductive knowledge in principle cannot explain historical phenomena. But it is possible to use the hypothetical-deductive theories of exact sciences in the modeling of some aspects of historical phenomena. It must be regarded as the cooperation of reconstructive (historical, descriptive-theoretical) and constructive (hypothetical-deductive) approaches but not as an attempt to replace one by the other [13]. It is also possible to use the reconstructive approach in modeling some parts of the cybernetic systems. In this case we can call this cooperation as well. From the perspective of modeling of the creative part of the engineering design process this type of cooperation seems to be more appropriate. We have to try to introduce the irreversible "arrow of time" (i.e. the reconstructive approach) into cybernetic models (e.g. by cooperation techniques; in this case it will be a rather synergetic model; this approach maybe needs a different computational algorithms/paradigm not invented yet) or, at least, to try to connect the computational system based on cybernetics with synergetic model. This should improve the initial models' architecture, their functionality and bring these models closer to the real life phenomena. The question is whether we could model the synergetic system that has characteristics of irreversible "arrow of time" by means of traditional computer (i.e. serial computational machine), which is based on reversibility principles.

As I. Prigogine showed in the language of mathematized science, the real situations are orientated in time, the states and the laws are closely connected with one another and that the initial conditions of the system emerge as the result of its previous evolution [13]. For a critical analysis of I. Prigogine's attempts to use exact science (based on mathematics) for understanding the natural-historical phenomena see e.g. [17]).

I. Prigogine has written that irreversibility can no longer be identified with a mere appearance that would disappear if we had perfect knowledge. Instead, it leads to coherence, to effects that encompass billions and billions of particles. He noted that we are actually the children of the arrow of time, of evolution, not its progenitors.

It seems that most of self-organizing systems have their inner goal, towards which they are constantly evolving, but to make this goal clear for us, humans, it is very hard (if not impossible) task. The essential characteristic of a self-organizing system is its autonomous purposive behavior. The characteristics of a self-organizing system cannot be constructed according to an external purpose (from the outside, regarding to the system). "Self-organizing systems … have their own (i.e. autonomous) goals…" [18].

If we get a successfully constructed synergetic model, which operates according to internal purpose, we will get a kind of a self-organizing system. Then we can introduce some external agent that performs reasoning upon the internal characteristics of the system in order to construct external conclusion or view, thus achieving an external purpose (interpreting the internal information). By doing that we could get a compound self-organizing system (i.e. synergetic model), which has an external goal. And this is relatively straight forward activity to construct such a system, since all (traditional) cybernetic and systems' engineering models function according to the external purpose. Maybe, in such a fashion, we can use the benefits of self-organizing systems in CAD applications and in ADS.

B. Modeling (reasoning) by analogy

This activity conforms to the evolutionary theory of systems development (including e.g. culture, human society). It happens that the human brain functions largely in the same way. Also the "learning" processes of the majority of biological species base on the principle of analogy. The idea is to try to create a model of such a learning system. The model could, in general, function as follows. Some cases/situations are presented to the system from which it may learn, i.e. acquire some information. The system (model) remembers this information and then in the future it may be capable not only of finding the exact learned cases but also the analogical cases. To accomplish this, the system must have some reasoning mechanism that allows recognizing analogies in the presented/surveyed information. In order to improve the model (in the sense of self-organization) we can add here the "historical component". The system remembers the case in the historical context, in real time; with the characteristics of the environment such as time, the source of the information etc. It is the system that takes into consideration the initial conditions of the process of information acquisition. It is important to underline that these initial conditions are not arbitrary as in conventional (classical) cybernetic models. It also could be possible to put the system under conditions of strong non-equilibrium in order to stimulate the emergence of the creativity. In such a way we could get a synergetic model that, in addition, functions similar to the majority of biological systems on Earth, including humans and the functioning of human's brain (in creativity context?).

C. Dreams' modeling

The idea of human dreams' modeling comes from the fact that sometimes the products of creativity arise during the sleep, when dreaming. Although the dreaming mechanism is not known well yet, it is possible to model it at the most primitive level of abstraction. Namely, it is suggested that dreams are composed of previously acquired information, of the interpretations of previous experiences and of the combinations of this data. The exact mechanism of the combining process is still unknown, but at the most simple level it is asserted to be a random combinatorial activity. In that case it is possible to model that combining process by means of traditional computing (IT). Assumption: the dream may consist of the entities previously known by the system. We need to create the algorithm of combining these entities (possibly fuzzy, random), and the mechanism of interpretation of these combinations. Some of the combinations may be useful in system's work. So we can state that dreams' modeling is a kind of combinatorial (random) activity on some known information segments, which, hopefully, may lead to the useful combinations of data that could be considered as a product of creativity. Again it is possible to add to the initial model the properties of the self-organizing system to optimize it and to improve system's performance. We can also use principles of synergetics in combination with other non-classical branches of science, for example with memetics. In [19] such an approach was used to explain and to create the alternative theoretical base of a given musical system. Memetics is a theory of mental content based on an analogy with Darwinian evolution. It purports to be an approach to evolutionary models of cultural information transfer. A meme, analogous to a gene, is an idea, belief, pattern of behavior (etc.) which is "hosted" in one or more individual minds, and which can reproduce itself from mind to mind. Thus what would otherwise be regarded as one individual influencing another to adopt a belief is seen memetically as a meme reproducing itself.

D. *Software agents*

Another AI technology that may be further improved using the synergetic approach is autonomous software agents. With this type of computational model it is suitable to model the behaviors of social systems. As a self-organization of society is connected with freedom of individuals, we can use a system of relatively independent (free) software agents to model a self-organizing system. The software agents' technology may be successfully combined with other AI technologies (neural networks, genetic algorithms e.g. [20] etc.) in order to improve a system even more. In [8] for example, a suite of independent software agents was developed that run on AutoCAD® platform. Software agents were connected with Artificial Neural Network (ANN) in the form of a separate agent that has ANN functionality and that is capable of being trained in a particular way. See Fig. 1 and Fig. 2 for an example of some

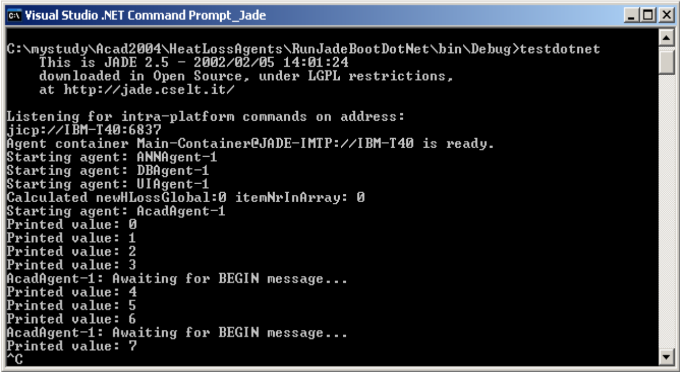

Fig. 1 Agent system waiting for BEGIN message

visual interfaces from the system implemented. (For an overview of the software agents' technology and its hybridization possibilities see [8].)

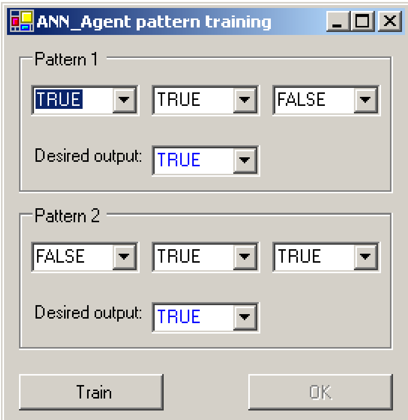

Fig. 2 ANN_Agent's user interface form

We then should include into the resulting system the characteristics of the self-organization, mentioned above, to get a candidate for a successful synergetic model.

IV. Conclusion

A. *Philosophical outlook*

In this section some concluding philosophical remarks on the subject are brought.

Stephen J. Gould in his works (e.g. [21]) stresses the importance of the historical character of the life. As we remember, different life forms may be considered as an example of self-organizing systems. The important property of self-organizing systems is their historical character of evolution. In his definitions he also notes that the human species are not necessarily the highest expression of the life on our planet and therefore, to put it objectively, we should not put ourselves into belief that our cognition mechanism might be the supreme and the right one. He notes that in order to understand the events and generalities of life's pathway, we must go beyond principles of evolutionary theory to a paleontological examination of the contingent pattern of life's history on our planet which is the *single actualized* version among millions of plausible alternatives that happened not to occur. Such a view of life's history is highly contrary both to conventional deterministic models of Western science and to the deepest social traditions and psychological hopes of Western cultures for a history culminating in humans as life's highest expression and intended planetary steward. Stuart A. Kauffman [22], [23], one of the leading figures in the study of self-organization and complexity nowadays has pointed out that the evolution of the whole world appears to be a combination of selection and self-organization. Thus the understanding of evolution only by natural selection is incomplete.

If we assume that the self-organization paradigm is true, then human mind, among all other known systems in our world, must function according to it as well. From that we can conclude that the human mind's creativity has to work in accordance with synergetic models as follows. In synergetics, models should ideally reflect the transitions between different qualitative states by *positive feedback* (a system exhibiting positive feedback, in response to perturbation, acts to increase the magnitude of the perturbation). These transitions are possible only if the influence of external environment on the system is so changeable that the amplification of the fluctuations may cause the system to move away from the equilibrium so far that it cannot return to the former state and there may appear new possibilities of development (i.e. creativity?).

These qualitative transitions are simultaneously both determined and undetermined. The fundamental objective indetermination lies in their basis. It is not determined into which qualitative state from some (or many) possibilities the system really goes after the selection. But the field of possibilities is determined. [9] These model' characteristics should comply with the theory of self-organization or synergetics that was introduced and thoroughly developed by Hermann Haken.

We also have to remember (while constructing, modeling some natural phenomena) that the scientist himself and his activity together with its products can now be treated as part of modeling process, of nature. Nature is understandable as a living being who, thanks to the conceptual and technical idealization, is indeed predictable, even transformable and manipulable, but only locally, partially and relatively [24].

As Zwierlein notes [25], one cannot approach any question at all from a neutral or objective standpoint. Every questioning grows out of a tradition and its underlying pre-understanding that opens the space of possible answers. To grow and to expand the horizons does not mean to surpass the condition of having a background of pre-understanding in principle. We will always operate within the framework the "Lebenswelt" provides for us. And it is definitely impossible that our understanding will ever be neutral or objective or complete.

We agree with Zwierlein at that point, but does it mean that mankind will never be capable to understand the surrounding integral world completely? Should we try to approach the problem of understanding from another perspective that is not based on traditional cognition (i.e. logical, cumulative way of thinking) or as Zwierlein and Kant note, is ultimately rooted in anthropology (scientific understanding)? For instance, one can try Taoist approach (meditative practices etc), but, although, the so-called enlightened adepts are reputed to realize (specifically, to realize not to understand – in Taoist practices these words have different meaning) the true meaning of life and integral world (Lebenswelt?), is this realization the true one? How one can check this against the truth and what is the truth itself? Moreover, every Zen master, for example, still has got slightly different realization (understanding) of things, although they insist that the core understanding is the same and the one. All these points just amplify doubts and uncertainties about humans' cognition mechanisms.

Hayek [26] suggests that while known biological species have adapted with fixed and rather limited environmental "niches" beyond which they cannot exist, human and some animals, rats, for instance, were capable to adapt almost everywhere on the planet. Hardly this was achieved simply by the individual adaptability alone. The author points out that the overall success of the human species our civilization owes to the social ability and cooperation of the individuals (which derives from self-organization?).

Let us conclude this section with a rather philosophical outlook on the problem. What would be the directions for further evolution of the mankind? Some people think that the acceleration of the development of the technocracy (in the meaning of hypothetic-constructive-deductive way of cognition, opposed to self-organization thinking) is an answer. And we can see that this way of thinking really dominates in today's scientific and domestic (every-day) domains. The alternative understanding, on the contrary, respects the appearances of Mother Nature in all aspects of reality and promotes the soft management and participative construction in accordance with the global self-organization. As Leo Näpinen notes [27], the big question is whether the human mind (spirit) will grow belonging to the general determinacy (comprising the creative chance) derived from the integrity of the world —, i.e. belonging to the self-organization, or the human mind will restrict itself to the splitting of the integral world into pieces and manipulating with them — i.e. will restrict itself to organizing the organizations.

B. Artificial creativity

Going back to creativity modeling, we should take into consideration that in order to model human' creative process we can use the analogy principle, for instance, only to some degree. This means that we do not know exactly how this process occurs in reality (e.g. dreams, emotions etc). We can rely only on some possibly true facts (knowledge) that today science has about it. Therefore, as a result, we can get only an approximation of the real system (artificial human creativity). Another point is that we are not really interested in examination of how this creativity really works (i.e. the objective of the research is not to ultimately expose the mechanism of creativity but to build the mathematical/synergetic model that is relatively creative (mathematical model's "creativeness" – in a sense of engineering design creativity – see above)), instead we want to model this phenomenon and use it in practical applications, which may help us do better design (engineering) work and automate engineering design process. On the other hand, in order to model the system successfully, it is useful to know how the real system works, at least on the conceptual level.

In addition, in all of these implementation examples, in synergetic models it is possible to use the principle of new mereology - the philosophical study of wholes and parts, which states that in dissipative structures (i.e. self-organizing systems) parts are modified by their composition into a whole. The existing versions of mereology rely on the assumption that parts are not changed by being associated into wholes. To put it simple, the sum of the single components' properties is not equal to the compound property (as a whole) of these components (in qualitative sense). In synergetic models combining parts of the e.g. information (composing into a whole) may lead to the emergence of new properties of the resulted compound system.

There is a need for a further and better research of the phenomenon of self-organization in the natural systems and in the synergetic models. Future developments in the science of self-organization are likely to focus on more complex computer simulations and mathematical methods. However, the basic mechanisms underlying self-organization in nature are still far from clear, and the different approaches need to be better integrated [28].

Learning the principles of self-organization, however, is not a simple task and needs careful and thinking approaches. While approaching this conception we must remember that our species (humankind) is not necessarily the life's utmost creation on this planet nor our understanding of the surrounding world is unconditionally adequate.

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