A Framework Supporting Creativity in the Design Process: A Systems-theoretic Perspective

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Abstract

This paper attempts to establish a systems-theoretic framework supporting creativity in the design process, where the design process is considered to have as its basis the cognitive process. The design process is considered as a purposeful and ongoing transformation of already complex representational structures and the production of newer ones, in order to fulfil an ill-defined goal. Creativity is considered as the result of an emergence of organisational complexity in each system participating in the design process, while it is trying to purposefully incorporate new constraints in its meaning structures. The meanings generated in each system are identified as the contingent and anticipatory content of its representations, and where self-organisation is the dominant process in which they are continuously involved. Furthermore, Peircean semiotic processes appear to provide the functionality needed by the emergent representational structures in order to complete the cycle of a creative design process. Creativity is located in the abductive part of the semiotic process, the fallible nature of which is maintained in the proposed framework by the fact that the emergent representations can be misfits. The nodal points of the framework are identified and analysed showing that such a design system can be creative in different dimensions.

Keywords: *Creativity, Representational Content, Emergent Anticipations*, *2*nd*-order Cybernetics, Peircean semiotics*

1 Introduction and Rationale: The Need of a Framework Supporting the Design Process

The rationale for a framework to support the design process is not to seek for a formalism to reduce the complexity of the design process, nor to produce models of structured representations to guide potential computer simulations. Such models would necessarily be much impoverished versions of reality, while any such framework would run into problems regarding contextuality and evolvability issues (Macmillan et. al., 2001). Rather this work seeks to show that an in depth understanding of the complex and dynamic nature of a design process requires a framework to support the modeling of such processes. A framework explaining the emergence and the functionality of interconnected representations of a system engaging in a design process would provide further understanding in order to facilitate creativity.

2 Design and Cognition

There are many contemporary efforts to define design and even more, to try to establish the basics that can be said to bring about the design process (Friedman, 2003). Friedman argues that most definitions of design describe it as a goal-oriented process, where the goal is a solution to a problem, the improvement of a situation or the creation of something new and useful. Given that the ability to act upon an environment in order to effect a goal-oriented attribution of a certain purpose belongs to a cognitive agent, design can be undoubtedly considered as a cognitive process. Thus any framework explaining and supporting the design process should be based upon a cognition framework.

For describing and modelling the design process, cognitive frameworks can be divided into two categories based upon the sets of principles that govern them. The first category is that of the classical causal cognitivistic/representationalist frameworks of cognition. These are either based on a static notion of information and knowledge structures which do not support the interactive nature of cognition (Fodor, 1975), (Newell, 1980) or they allow for a causal evolutionary approach to cognition and representations by adhering to the superiority of the environment for the guidance and selection of this evolution (Millikan, 1984) (Dretske, 1981). The second category consists of cognitive frameworks based on the systemic and dynamic properties of emergence and self-organisation. It is these properties that are fundamental to the approach described in this paper.

2.1 Cognitivist Frameworks of Cognition and their Implication to Design

The cognitivist frameworks of cognition are primarily based on the hypothesis that the cognitive system processes symbols that are related together to form abstract representations of the environment. In the most extreme case the processing is assumed as deterministic and the environment as pre-given. In the evolutionary version the information processing is guided by the laws of natural selection imposed by the environment. In both cases, the primary ingredient of these representations is causal information provided by the environment. The cognitive system is then acting based on the representations.

The major negative implications of the cognitivist frameworks in modeling the cognitive process are due to the encoded nature of the representations. Each encoding results in a representational content which relates the cognitive system with the environment. The problem this raises, setting aside the examination of the nature of such a representation, is to find the source of this content. In (Bickhard, 1993) it is argued that such encodings are just 'relationships of representational content transfer'. Cognitive frameworks of cognition do not give any answer about the source of the representational content. Consequently, the cognitive system needs a set of predefined representations in order to progress any cognitive process. Its representational content (or meaning) is either static or externally determined and imposed. Since meaning is externally transferred but internally processed, the syntactic and semantic aspects of the cognitive system are separated, making the creation and enhancement of inherent meaning structures impossible. Information is taken as the vehicle of exchanging objective meaning structures between system and environment. The realisation of cognitive processes based on predetermined meaning structures deprives the cognitive system of the property of creative and inherent intentionality. Even accepting that the initial intentionality is represented by the existent meaning structures of the system, this is as far as it can go. This type of intentionality is purely referential and is independent of the context of the interaction. Such a cognitive system exhibits limited adaptability in the face of the continuously changing demands of a dynamic environment.

The application of the cognitive frameworks of cognition to the design process merely reduces the latter to a rule-based and algorithmic process. There are numerous related problems. The design process takes the forms of algorithms operating within a finite and universal representational space. The design process system needs to formally represent the domain of interest and then find some method of sequentially searching the resultant problem space. This means that all of the possible representational states must be defined before problem solving can begin. The information set used by the design process system is assumed to be universal and predetermined in every context of interaction. This limits the artifact's adaptability. There is no mechanism for the incorporation of new meaning structures, based on feedback from the user of an artifact created by the design process system. This means there is a separation between knowing and doing. This removes the constructive dimension of the design process and the design system cannot contribute in a direction that is not specified in the initial design space.

2.2 Essentials of the design process and the inadequacy of the cognitivist frameworks

2.2.1 Design problems are ill-defined

These rule-based and causal approaches in modeling and analysing the design process would be successful if design problems were well-defined. A design problem has many solutions. The most appropriate one would be selected based on how well it satisfies the respective constraints. This presupposes that all the constraints are already given at the conceptual design phase and that their influence in the design problem is predetermined. This is rarely the case (Goldschmidt, 1997), except for well structured subproblems of a larger problem space such as those sometimes found within engineering design, and where human activity plays a minor or non-existent role. Most design problems are defined in terms of information about the people who will use the artifact, the purpose it has for them and the form the artifact should posses in order to be successful. Such design problems are ill-defined and the possible solutions are not clear from the beginning. Finding a solution requires in addition finding out what the real problem is. Solving and specifying are developing in parallel and drive each other. Claiming to have reached a static specification phase of the design process after the conceptual phase, because of clear understanding of the design problem has been reached is also rather misleading since solutions and problems co-evolve during the whole design process (Heylighen and Bouwen, 1999).

2.2.2 The design process needs an interactive framework

The ill-defined nature of a design problem makes both the goal state and the respective constraints highly ambiguous. An internal evaluation of a possible solution is not enough. Such an evaluation would be subjective and disregard real world needs. Internal evaluations of a closed system's actions are bounded to its initial organisational complexity. The lack of valuable information from the system in all stages of the design process is confronted by the opening of its boundaries to interact with the environment. As it is said in (Jonas, 2001), there is a need to grow the internal complexity of a design system to deal with the increasing external complexity. Putting the design process in an interactive context offers this possibility since now representation, meaning and information can be examined in a different perspective.

2.2.3 Design content is not the artifact itself

The assignment of the design process to an interactive context raises the importance of the user of the design process outcome (the artefact). Users evaluate the artifact on the basis of their own individual experience. Considering that each user's experience and hence representational structures are different, the content of the design process should not be only understood to be the artifact itself. Indeed, as it is argued in (Kazmierczak, 2003) the content should not be attributed to the aesthetical and practical properties of a fixed object. The content of the design process is subjectively interpreted and changed by the user's cognitive processes. The design system should now provide a form to a dynamic and ill-defined content in such a way that will facilitate its creative interpretation by the user/receiver.

2.2.4 Design need to be anticipative

The interpretation of content from multiple receivers with different representational structures implies that the design system has the potential to consider many possible outcomes and consequences of its actions before it proceeds to their realisation. This does not necessarily require a known universal information set and a predetermined design problem space. As (Rosen, 1985) such a past-oriented anticipation needs a model of cause and effect operating on an infinite regress. On the contrary, in the design process anticipations should be placed in a pragmatic context and be projected against the future, using different directions and time scales, (Nadin, 2000), (Jonas, 2001). As it will be shown below, such anticipations are emergent in the design process, they anticipate the possible future and they can be inappropriate. This kind of anticipation shifts the traditional perspective of intentionality and instead aids the emergence of a creative design process at the social level.

3 Creativity in the Design Process

Creativity, as a possible property of a cognitive process and consequently of a design process, is very hard to define. The problem is twofold. There is the difficulty to capture the notion of the design process as creative and also, there can be no guarantee for its occurrence (Dorst and Cross, 2001). The literature of research in creativity is huge and spans a great variety of scientific domains (Simon, 1988), (Health, 1993), (Martindale, 1995). Boden (Boden, 1990) proposes the exploration and further transformation and expansion of well-formed conceptual spaces of a cognitive system as the basis for creative actions. Simon, in his attempts to construct an algorithm for implementing creative processing in a machine, models creativity as a three-staged process. Simon argues that in a creative process one should define the problem as concretely as possible, find the necessary heuristic rules and the solution (Liu, 2000). Needless to say that still, even now, a machine substituting for a cognitive process can only search through the conceptual space already provided by its designer. The representational structures of this space represent the two sub-processes recognised by Simon, leaving the last one at the machine (Brown, 2002). The problem with this approach remains even in a context that is independent of machine implementation. The emergence of personal creative activity is supported but the opportunity for further evaluation, and possible integration, of the newly generated structures from the receiver and the design system itself is not provided. On the contrary, in Csikszentmihalyi’s framework (Csikszentmihalyi, 1996), the persistent examination and acceptance of a personal creative process on a social level are required in order a design process to be recognised as truly creative. Finally, (Dorst and Cross, 2001) take one step further proposing that in a creative design process there is a co-evolution and a respective interchange of information between the problem and the solution space.

The presence of future-oriented anticipations as well as the interactive nature of the design process calls for the examination of creativity in an evolutionary framework supporting both the personal and the social dimension.

3.1 Self-organisation and Creativity

If the design process is examined in a cognitive framework based on 2nd order cybernetic epistemology, then,, a cognitive system is able to carry out the fundamental actions of distinction and observation. It observes its boundaries and is thus differentiated from its environment. As the system is able to observe the distinctions it makes, it is able to refer back to itself the result of its actions. This makes it a self-referential system, providing the ability to create new distinctions (actions) based on previous ones, judging its distinctions and increasing its complexity by creating new meanings in order to interact (Luhmann, 1995). The self-referential loop can only exist in relation to an environment, but it also disregards the classical system-environment models, which hold that the external control of a system's adaptation to its environment is replaced by a model of systemic closure. Due to that closure, the self-reference of an observation creates meaning inside the system, which is used as a model for further observations in order to compensate for external complexity. Each new operation based on observations is a construction and also an internal increase of the organisational complexity of the system. This process of emergent increment of order is a process of self-organisation (von Foerster, 1960).

As the self-organised system evolves and interacts via structural couplings with its environment, it creates a internal network of interconnected structures representing its history and experience (Maturana and Varela, 1980). Their continuous internal differentiation creates certain functional subsystems with non-linear interrelations. A self-organised system is a dissipative system exhibiting a 'far-from-equilibrium' organisation. Therefore, at any time, there are some internal dominant constraints suppressing all the rest and guiding the system's organisation. In the subsequent interactions the system would be subject to external perturbations, which would be evaluated on the base of pre-established structural couplings. Creativity is considered as the result of an emergence of a new form of organisation in a self-organised system, while it is trying to purposefully incorporate new dominant constraints.

Following on from this, each system participating in the design process is considered as a self-organised system. For the purpose of the present analysis two such systems can be defined: the design system and the user system. Consequently, the design process is seen as an interaction between two self-organised systems in order to build ever more adaptive models towards ill-defined outcomes. The functional aspect of design becomes the purposeful and ongoing transformation and expansion of already existing representations. For each system, a different representational content is internally emerging from the bilateral attempt to incorporate an artifact, as a perturbation and not as a static informational structure, into their organisation.

Although there is not a logical sequence of the interaction, for the benefit of this analysis, it can be said that the design system attempts to communicate its representations to the user via the creation of an artifact. The aim of the communication is to induce, in the user system, the emergence of the necessary constraints that will guide its organisation to a new order, facilitating its actions towards an ill-defined problem. Thus, the design process is a purposeful communication between two or more self-organised systems via the use of the artifact as the common cognitive interface. This has two implications for creativity in the design process. The first one is that the self-referential nature of the design system provides the ability to the system to exhibit creativity within the boundaries of its closure. Simultaneously and due to the closure of the design system, as well as of the user, the effectiveness of the artifact resulting from the creativity of the design system is not assured. This adds the social dimension of creativity. The second implication flows from the first and imposes a great responsibility upon the design system regarding the effectiveness of the artifact. The more creative the design process the deeper and more profitable the structural coupling between design system and user. This makes the design system responsible for something that in principle it can only perturb. The richness of the user's organisational structures will play a very important role in the effectiveness of this perturbation, but the design system would have to anticipate the degree of this richness. This adds to the difficulty of creativity in the design process.

Therefore, although, the placing of the design process and creativity in a self-organised framework of cognition provides us with an abstract description of the respective properties and prerequisites, but gives us no answer regarding the framework's functionality or the way that creativity can be identified and observed. A further complication is that there is an established rejection of the notion of representation in the self-organised approach to cognition (Varela, Thompson, and Rosche, 1991), (Port and van Gelder, 1995). In an attempt to deal with these problems, in the next section a model that supports the emergence of representations in a system's anticipations of future possible interactions is introduced. This leaves behind the traditional notion of a general-purpose algorithmic representation, implying that any representational functional organisation is an emergent product of the interaction between system and environment.

3.1.1 Emergent Representations and Anticipations

Bickhard (Bickhard, 1993) postulating a self-organised system (Bickhard uses the term "recursively self-maintenant system") and its functional subsystems, argues that in order for such a system to be adaptable towards a dynamic environment, two properties are required. The system should have a way of differentiating environments and a switching mechanism in order to choose among the appropriate internal processes. The differentiations are implicitly defined by the final state that a subsystem would reach after the system's interaction with a certain type of environment. Although such differentiations create an epistemic contact with the environment, they do not carry any representational content, thus they are not representations. Rather, they indicate the interactive capability of system's internal process. Such differentiations can occur in any interaction and the course of the interaction depends on the organisation of the participating subsystem and of the environment. A differentiated indication constitutes emergent representation, the content of which consists of the conditions under which an interactive strategy will succeed in the differentiated environment. Bickhard calls these conditions "dynamic presuppositions" and argues that this content emerges in system's anticipations of interactive capabilities. It is the anticipation that could be inappropriate and this is detectable by the system itself (Bickhard, 2001). This type of anticipation is very different from the one supported by the cognitivist models of representation, which are trying to find a mapping of the environment to their past decisions. Here, the activity is future-oriented and it can be inappropriate, if the chosen interactive strategy does not internally yield the desired results.

3.1.2 Dynamic Anticipations in Design Process

It has already been noted that the ability of the design system to anticipate the richness of the user's organisational structure is very crucial in creativity. Considering the dynamic and future-oriented type of anticipation described above, it can be said that each system participating in a design process should have the capability for anticipative interaction with the environment in order to achieve the closure conditions that will give it the opportunity to satisfy its constraints. The problem is that all possibilities and selection cannot be inherent in the organisation of each system. A possible solution is that the system should evolve learning capabilities. This would provide the way to expand its dynamical anticipation capacity and its ability to evaluate a possible interaction. The system becomes less dependent and more sensitive regarding its contextual interactive capabilities. It increases its ability to better recognise its environment, evaluate the conditions and properly formulate its goal regarding the problem (Christensen and Hooker, 2000). This provides a infrastructure better suited to the design system to define the design problem and anticipate the possibility of success in the emergent interactions between the user and the artifact. The structural coupling is strengthened and the creativity acquires a more prosperous field of emergence. Of course not every external perturbation is useful for a dynamical anticipative interacting system. Only those contributing to the system's closure and therefore to the preservation of their self-organisation would be selected for further exploitation. Since in the proposed framework closure is achieved at the level of differentiations and of the respective emergent representational content, creativity cannot be clearly defined, nor statically identified. Rather it has the nature of a process-oriented and evolutionary character. Furthermore, the progressively increasing capability of the system's anticipation creates an intentional capacity. This is not the same as the traditional notion of intentionality considered as the sum of all system's representations. Intentionality derives from the system's capability of purposeful interaction and accordingly is measured. This makes creativity an intentional and dynamically anticipative cognitive process.

3.2 Semiotic process as vehicles of emergent representations

In this paper, the consideration of representations as emergent in a system's anticipations of interactive potentialities allows for the existence of representational content in a self-organised context. Moreover, this representational content is responsible for guiding the design system's interaction and accordingly its creativity. A problem that still remains is to find a way to follow and observe these representations. Indeed, it is very important that the representations emerging in a design process are indicated in order for the design system to be able to manage their functional effectiveness during the design process. Following (Brier, 1996) who proposed the use of the Peircian semiotic framework as a medium of signification for complementing Luhmann's social-autopoietic theory, the Peircian semiotic processes are examined to see if they can act as a vehicle for the emergent representations. Specifically, Peircian semiotics provide a functional framework for the indication of important nodal points and their representational content in a self-organised system's intentional interaction (Arnellos, Spyrou, Darzentas, 2003).

In a Peircian semiotic process (Hartshorne, Weiss, and Burks, 1998) a complete sign is the one in which a representamen (sign) refers to a ground, to a correlate (sign-vehicle) and an interpretant, which is itself a more developed sign. The ground of the representamen is the sort of idea in reference to which the sign stands for its object, as it does not stand for it in all respects. The sign-vehicle is the representative element, the foundation over and above which a relation arises. In principle, the sign vehicle can be implemented in any kind of structure. Independently of its implementation, it is the element responsible for the conveyance of the object signified to the cognitive system. The sign-vehicle is often called a representamen. A cognitive system may link the sign-vehicle to its signified object.

Applying this to the interactive and dynamic context of design, as it has been described so far, it can be said that the design system creates a sign (and not an object) that is interpreted by the user. The relation between the design system and the user is founded over the sign-vehicle (artifact), which plays the role of the representamen. Due to the organisational and therefore representational closure of the interacting systems, there can be no direct determination of the designer's representational content from the user. The design system tries to realise this content in a form which is the ground of the representamen. The ground is understood as form, as only as such can it preserve the characteristics of the designer's representational content, while allowing it to be realised by a different cognitive process from the user. Accordingly, the mediator (representamen) will exhibit this form by means of some qualities, the properties and relations it has independently of whether it serves as a mediator. It is the qualities, properties and relations of the sign-vehicle that determine and constrain the form of the ground. The form of these qualities, properties or relations is what has been mediated from the design system to the mediator. The latter will determine the ground of the representation for the user. The designer is responsible for the creation of a mediator in such a way that will have the ability to include these aspects of the sign which concern its relation to the user.

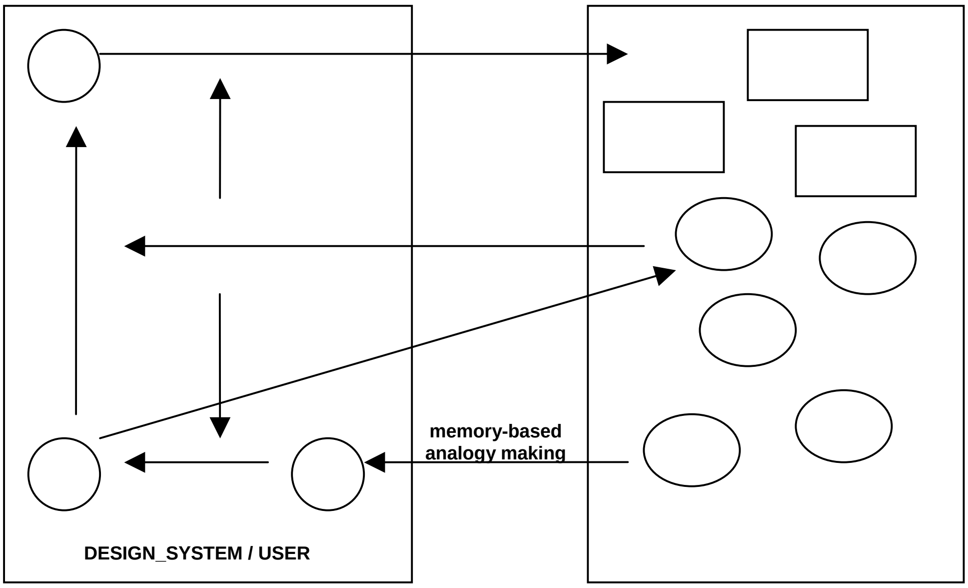

Fig. 1. Nodal points and functionality of emergent representations in a design process.

Due to space limitations an analytical description of the types and properties of the representational relations cannot be given, but a useful analysis of the representational content regarding the relations between mediator/sign-vehicle, mediator/interpretant and sign/interpretant is given in (Lizka, 1996).
As shown in Fig 1 – examining the case, where a user is interacting with an artifact – before the user decides to interact with the artifact, there is only the dynamic object (DO), which is the artifact with respect to the designer. When the user system decides to interact it firstly proceeds to memory-based analogy-making and indicates the nature of the DO by a differentiation which forms the immediate object (IO). At this moment of the interaction, the sign-vehicle indicates the direction of the reality to which it refers. It contains several IOs which in turn refer to several DOs. Which IO will eventually be realised depends on the system's anticipations. The given signal provided the ground for the object's perception, or its correlation to the designer's representational content. There will be many internal tests needed for this core meaning to be temporarily stabilised into a dynamic interpretant (DI). At this point the external signal formed within the artifact begins to have a semantic effect on the user. The, 'objective meaning' (DI), which results from the semantic processes, needs to allow for revision. This requires morphodynamical processes to dynamically manipulate meaning structures in terms and by means of internal indications, which are simultaneously tested against the system's anticipations (pragmatics) within the conditions of the functional closure offered by the dynamics of the system. Ideally, the user identifies with the intentionality of the designer, intentionality that is immersed in the artifact, and then the final interpretant (FI) has been reached.

4 Interrelated Dimensions of Creativity

4.1 Creativity and Abduction

In the context of semiotic processes abductive reasoning is considered as the base of creative thinking. Abductive reasoning is derived from the experience of surprise in a system's perception of its environment. In the proposed framework, the experience of surprise is modelled as the perception of difference between a system's anticipations and perceived environment. It is the point where a well established interactive strategy consisting of a network of indicated interactive capabilities conflicts with the present differentiation. This time the IO cannot be actualised based on the system's anticipations. Instead the system has to proceed to a new differentiation of the environment in order to be able to change its interactive strategy and confront the new situation. This differentiation can be in error, as the inference of a new IO (in respect to the present situation) has the nature of guessing. In that case, the indicated interactive strategy will not have the desired results and it will not be incorporated in the overall organisation. Nevertheless, abduction is the system's only way to introduce a new differentiation resulting in the creation of new representational content. It underlies the system's capacity for open-ended epistemic contact with the environment. In terms of a designer system it is the selection of a new IO resulting in a formation of a new II (intermediate interpretant). It is hypothesis-making regarding a possible solution to an ill-defined problem and constitutes a presupposition for the next level of creativity in a dynamical anticipative interactive system. This kind of representational content is highly contextual and local, residing inside the boundaries of the respective design subsystem.

4.2 Codification of Emergent Interactive Potentialities

This process requires the properties of the self-organising part of the system, which will try to incorporate to its structure, the intermediate interpretant (II) that is under examination. This requires self-reference and functional closure since the system must refer to itself in order for unsuccessful structure modifications to be obliterated. Certain user anticipations may not be fulfilled by the artifacts, and this amounts to inappropriate designer's expectations. This is the reason for incorporating the pragmatic aspect of the representation. It is the passage from the II to the DI, which codifies the new differentiation and categorises the emergent representational content. This codification externalises the surprising event to a context-independent group of people (Heusden and Jorna, 2001). The communication of this content outside the boundaries of the respective subsystem certifies the need for external evaluation of a creative event. It also constitutes a presupposition for the next level of creativity. At this phase the system is able to formulate the goal regarding the hypothesis of a possible solution in the first creative level.

4.3 Learning

The codification of the system's interactive capabilities in the context of dynamical anticipation makes possible the examination of the relations between the respective representational structures. This improves the system's anticipations and enhances the design process, as now the design system acquires the abstract knowledge needed to operate at the level of the relation of anticipative indications. The system increases its ability to localise sources of success and error, hence evolving the capacity to preserve its closure. This provides the prerequisite for the evaluation of anticipations in a design process. At this phase the system is able to infer an explanation of the characteristics a solution of a certain goal should have.

The relation between the three described levels is neither linear nor sequential. The three levels and the representational structures of the respective subsystems are continuously altered via system's interaction. In this way a design process may move from a creative event to a model formation, which is coded into an artifact in order to be communicated. As has already been stated, the effect of this creative event is not assured. What is feasible in the proposed framework is that the degree of capability of a creative design process is bounded to the dynamical anticipatory capacity of all participating systems. The intentional interaction of the user with the artifact will create new perceptions, thus new possibilities of conflicting anticipations, therefore, inducing user's action towards creative processes.

5 Conclusions

Design should have a cognitive foundation. The cognitivist frameworks of cognition based on representations defined on a merely causal and predetermined information correspondence does not offer the necessary variety to study neither the design process nor creativity. An analysis of the design process in a framework of 2nd order cybernetics has been attempted. This has shifted the design process to a process of meaning communication between the design system and the user. The role of the emergent representations and their interactive and anticipative nature has been noted. Their type, relations and functionality have been indicated by the incorporation of semiotic processes. It is believed that the attempted analysis combined with the richness of the Peircian semiotic structures provides a way to identify the kind of representations emerging in a design process, as well as their respective functionality. The nature of creativity and its nodal levels are described. The framework aims at providing a way of explaining the different dimensions of a creative process and also, to stimulate the conditions for its appearance. Future work is oriented towards the use of this framework as a central point of reference to develop and examine methodologies supporting creativity.

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