ARTIFICIAL INTELLIGENCE AND EMERGENCE IN ARCHITECTURE: A MULTI-AGENT BASED MODEL FOR DESIGN PROCESSES

Eduardo Lyon
College of Architecture
Georgia Institute of Technology
Atlanta GA USA
eduardo.lyon@coa.gatech.edu

Abstract:

The purpose of this paper is to provide an alternative approach to traditional design process formulation and elaboration. In contrast to traditional models of design process fundamentally defined by the abstract manipulation of objects, this study recognizes that the resources available for rethinking architecture are to be found in a reformulation of its theory and practice. This reformulation should be based on non-linear design processes in which dynamic emergence and invention take the place of a linear design process fixed on a particular object evolution. Design is possible to be defined in two different and commonly confused ways; one as the process of designing or design activity and the second as the product of designing. In this study, we are concerned with design as a process to emphasize the misconceptions, derived from studying design products solely. Therefore, we propose a change from a design knowledge based on objects to a one focused on design as a network of processes.

1. Introduction

Advances in computational thinking and technology have stimulated the design and formulation of a large number of design software applications. Its elaboration anticipates a new conceptualization of architectural knowledge that frames and enables the elaboration of any architectural project. The conceptualization embedded in new CAD-based tools precedes the artifact's elaboration process; therefore, it constitutes a preliminary datum for its comprehension, and thereby is of theoretical importance.

2. Design as a process

Design may be defined in two different and commonly confusing ways. One definition regards the process of design or the design activity and the second views design through the product that has been designed. The following discussion concerns itself first and foremost with design as a process and emphasizes the misconceptions that come from studying products. We would like to argue that the core issue in design is establishing a process that builds internal insights and abstractions that are manifest in the tangible product. We propose a change from a design knowledge based on objects to a one focused on design as process.

3. Design process models

As a result of an increasing demand for rational, predictive procedure within design practice, a host of design methodologies appeared during mid sixties. In contrast to practices that appeared to many as neo-romantic appeals inspiration – really another version of black box models of design – there were multiple efforts to apply what was proclaimed to be a more scientific method that emphasized the rational and accessible control of the designer. During the early seventies a second generation of methods appeared that often was taken from problem solving methods and participatory problem solving methods. In the past twenty years, computational models have been added to problem solving methods. More recently, we find ourselves exploring cognitive models that seek to approach design problems not only from the vantage point of the objective but from an understanding of the shared cognitive setting in which they would be used.

Even though we can detect a clear evolution in design process models, most can be grouped under a sequential process paradigm. Sequential models assume design process as a sequence of stages and understand the design process as linear. Here the process resembles what in science is viewed as a Newtonian or mechanistic model. For us, the main concern involves the active, dynamic relationship between science and architectural design. Rather than remaining fixed in obsolete models of science, design should give far more attention to research in the co-evolution of design in different fields.

4. Evolutionary design

Evolutionary design has constituted a leading edge in design research in the last decade. Its application comprises the use of several evolutionary computation or artificial intelligence techniques to generate design solutions. Overall, methodology consists in the use of algorithms to increase and optimize the design-solution space. The approach — based on what is known as the neo Darwinist model — combines ideas from genetic theory from Mendel and evolution theory from Darwin to explain processes of natural evolution.

4.1. Genetic algorithms

Genetic algorithm introduced by John Holland in 1975 and initially applied to research related to natural and artificial systems is now applied in several other areas that primarily concern optimization of existing solutions. Genetic algorithms are applied to an initial population of individuals, each one including a genotype and a matching phenotype. Phenotypes are collections of parameters and genotypes are coded versions of the phenotypes. Each coded parameter is denominated by a gene. A collection of genes is a genotype and is usually represented as a string. In an evolutionary design process, artifact-genotypes combine to produce new versions that are then filtered through a fitness concept.

4.2. Neural networks

Neural networks within architectural practice comprise collections of units that containing functions or simple processing elements that may be activated. For example, the replication of crowd movement through a defined space by using AI algorithms permit the definition of parameters that may be used to gauge the relation between total number of units representing people and crowd behavior. The technique imitates actual neuron ensembles and their behavior when activated. Design applications are derived from the fact that a particular design defines parameters that can then be tested.

4.3. Shape grammars

Shape grammar has been used to analyze and to describe designs, and to produce variations based on the same grammar. A shape grammar consists of shapes, labels, shape rules, and an initial shape. Shapes and their labels are the basis for the definition of shape rules. Given an initial shape, one transforms it using the rules of the grammar to produce a new shape or shapes. Successive use of the grammar's rules on an initial shape produces designs. Shape grammars perform computations with shapes in two steps: detection of a particular shape and its possible substitute. Rules specify the particular shapes to be substituted and the manner in which they are replaced.

5. Emergence in design

Drawn from artificial intelligence and biology theory, emergence describes non-deterministic, self-organizing phenomenon that arise from local interaction between low-level units within a system. In many cases, design interpretation, charged by questions that appear to be drawn from the setting of emergence shows that the concept is misunderstood or applied with limited understanding. The design research community working with shape grammar, genetic algorithms, or their combination claims emergence as one of the most relevant advantages of using these techniques. Even though, global patterns emerge from local conditions, there is really little that is useful here. Shape grammars generate shapes since the minimal unit is a shape, and genotypes recombine. Even though they are subject to mutation, they generate nothing but genotypes.

6. Autopoiesis and architecture

The theory of Autopoiesis, proposed by Humberto Maturana and Francisco Varela in 1970, argues that a living system embodies a continuous process of self-organization and emergence. According to Maturana and Varela, living systems are self-producing systems. In contrast to assumptions that viewed living systems as generators of something different from themselves, Autopoiesis approached systems as simultaneously producers and products. Since an autopoietic system is organized as a network of processes of production that ultimately produce the system itself, they could claim that cognition was intimately linked to biological phenomena. Acting as a network of processes, the autopoietic system bears two distinct consequences. In the first, organization is understood as a network of production that makes the system possible; in the second, a particular structure constitutes a distinguishable component in the topology of the network.

6.1. Ontology of reality

The world in which we live is constituted by our perception, and it is our cognitive structure that enables us to have these perceptions. So, our world is the world that we perceive. If the reality that we perceive depends on our structure, there are as many realities as individuals. Such a position explains why what has been called "purely objective knowledge" is impossible. Since the observer cannot be separated from the phenomena he or she observes, we are determined by a cognitive biological structure in which the environment can only trigger alterations shaped by the structure of the organism itself. If our perception constitutes only a portion of the whole, the same is true regarding our overall knowledge of the world. Maturana draws an even more challenging conclusion when he argues that that higher human functions do not take place in the brain.

6.2. Design process as an autopoietic process

Given the limitations of previous evolutionary design process described above, we notice that Varela and Maturana provide grounds for approaching the constitution of design through cognition that is distributed or socially situated rather than dissecting the condition of one artifact in order to seek its replication through genetic code or grammar manipulation. It is through such a process that we may locate the emergence of novel design. It is precisely in such a way that we can understand the design process as fundamentally transformative and evolutionary process separate from the meta-stable replication of information.

6.3. Design process as emergence

The design research community has used the concept of emergence since the early nineties although with the limitations noted above. A more thorough analysis of the misconceptions that have accompanied emergence in architectural design and AI has been provided by Mary Lou Maher. Drawing on Maher's analysis, we would argue that in order to seriously reengage the concept of emergence within the design process, it is essential to change our model from one strictly based on objects and its behavior from one based on approaching relations as indissoluble from the process that constitutes the system.

7. Multi-agent based simulation

Agent based models are grouped under distributed artificial intelligence as well as in the field of distributed computation. In a general these areas view systems as composed by modules

called agents that presents characteristics such as autonomy, mental state and agency. These modules are called agents because of their agent properties or ability to organize themselves and make decisions either collectively or independently through the use of interaction protocols. Agents take on actions under specific conditions within a system that is characterized by a specific architecture. Design of agent-based systems requires that one specify not only the agent and system's architecture but also the modes for interaction and control. Because of their capacity to capture information about objects, multi-agent based simulation seems to be an adequate modeling technique to simulate design processes.

8. Conclusions

In a subsequent analysis of evolving projects the authors will explore in further detail ways in which one may integrate information acquired in the non-linear design process within the evolutionary model formulated by Varela and Maturana. In particular, in our future research, we will perform a series of protocol analyses focused on tracking design moves and their significance within design processes. Such information will be essential in order to propose a multi-agent based model of design process. This model will provide a conceptual framework for testing and developing a range of design tools. Desired improvements include capacity for better data structure manipulation and a graphic interface that will visualize the emergence of design and the understanding of design process itself.

References

1. de Vries, M., N. Cross, and D. Grant, Design methodology and relationships with science. NATO ASI series. Series D, Behavioural and social sciences, ed. N.C. M.J. de Vries, D.P. Grant. Vol. 71. 1993, Dordrecht ; Boston: Kluwer Academic Publishers. 327.
2. Dorst, K. and J. Dijkhuis, Comparing paradigms for describing design activity. Design Studies, 1995. 16(2): p. 261-274.
3. Liddament, T., The computationalist paradigm in design research. Design Studies, 1998. 20(1): p. 41-56.
4. Saunders, P.T., G. Di Cristina, Editor. Nonlinearity: What it is and Why it matters, in AD: Architecture and science. Wiley-Academy: Chichester,England. 2001, p. 223.
5. Mitchell, M., An introduction to genetic algorithms. Complex adaptive systems. 1996, Cambridge, Mass.: MIT Press. 205.
6. Frazer, J., An Evolutionary Architecture. Themes vii. 1995, London: AA Publications. 128.
7. Holland, J., Emergence: from chaos to order. Helix books. 1998, Reading, Mass.: Addison-Wesley. 258.
8. Grierson, D.E.H., Prabhat, 1956-, Emergent computing methods in engineering design: applications of genetic algorithms and neural networks. NATO ASI series. Series F, Computer and systems sciences, ed. P.H. Donald E. Grierson. Vol. 149. 1996, Berlin ; New York: Springer. 350.
9. Stiny, G., Introduction to shape and shape grammar. Enviroment and Planning B, 1980. 7: p. 343-351.
10. Stiny, G., Shape rules: closure. continuity and emergence. Enviroment and Planning B, 1994. 21: p. 1-29.
11. Poon, J. and M.L. Maher, Co-evolution and Emergence in Design. Artificial Intelligence in Engineering, 1997. 11(3): p. 319-327.
12. Basil, S. and E. Edmonds, The cognitive basis of emergence: implications for design support. Design Studies, 1996. 17(4): p. 451-463.
13. Maturana, H.R.V., F.G., Autopoiesis and Cognition. 1980, Dordrecht: Reidel.
14. Thacker, E., Biomedia. Electronic Mediations Ser. 2004: University of Minnesota Press.
15. Maturana, H., E. Goles, Coversaciones con Humberto Maturana, Editor^Editors. 2000, Universidad de Chile: Santiago Chile. p. Interview.
16. Maturana, H.R., G.A.M.E. Lenneberg, Editor Biology of language: Epistemology of reality., in Psychology and Biology of Language and Thought.. Academic Press: New York. 1978.
17. Varella, F.J., Ethical Know-how: Action, Wisdom, and Cognition. first ed. Writing Science Series. 1999, Stanford CA: Stanford University Press. 86.
18. Wilson, R.K., Frank C., The MIT encyclopedia of the cognitive sciences. 1999, Cambridge, Mass. 964.
19. Shen, W.N., D. H. Barthès, Jean-Paul., Multi-agent systems for concurrent intelligent design and manufacturing. 2001, London ; New York: Taylor & Francis. 386.