The problem of design in complexity research

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Abstract
This paper discusses the contribution of design research problems and abstractions in the formation of a complexity research agenda. Design is a capacity associated with systems that are often characterized as complex - but does design imply a general capacity and class of research problem that is inextricably linked with the complexity of a system? This is a rather uncommon enquiry even though the relation between design and complexity has been explored under two themes: the complexity of design, that is the identification and measurement of the complexity of design objects, processes and problems; and the design of complexity, that is the construction and management of complex (artificial) systems. However, these are mainly applications of complexity concepts and measurements in design research and practice rather an investigation of the meaning of complexity based on the design capacity of systems. The purpose of this paper is to discuss the mathematical basis and problems of a design theory of complexity and demonstrate the uniqueness of design as a distinct problem in the context of a complexity research agenda.

Complexity research is too versatile to be described by an indisputable research agenda. However there are a number of traditions and problems that can characterize the meaning of complexity and the scope of complexity research. For instance, complexity has been identified with the combinatorial capacity of systems; scaling; the capacity to exhibit certain types of critical behaviour or attracted to critical states; the evolutionary capacity of systems, associated with problems of cooperation, competition and reduction of variety; and finally the organizational capacity of systems. For developing the argument of the paper the focus will be on the latter aspect of complexity research.

In this investigation, complexity is associated with the capacity of a system to exhibit a certain type of organization. The motivation for this is that certain types of organized systems, such as the brain, organisms or societies, can exhibit complex functions such as intelligence, life, or governance. The main question is two-fold: first, to identify the organizational conditions that enable such capacities to emerge; and second, to identify the capacity that explains how these organizational conditions are produced and maintained. The production and maintenance of the organizational conditions of a system generally alludes to the capacity of the system to change the structure, behaviour or function of its environment (or its perception of this environment) and through this change to transform itself. Typical examples of such capacities are distinction and intentionality, autonomy and control, creativity and learning, anticipation and - as we claim in this paper - design. Design in particular alludes to the capacity of producing organizational changes in the environment of a system that increase the complexity of the system relative to its environment. Irrespective of where one chooses to embody or allocate this capacity, the special characteristic of design problems -in distinction to other abstractions such as machine, control or evolution- is that the complementary nature of the relation between system-environment is not a given but it is the problem itself.

Goguen and Varela ([1], [2], [3]) have explicitly associated the complementary relation between system and environment with the category-theoretic concept of adjunction. The same adjoint

relation can be implicitly found between allonomy and control, machine and language but also to other organizational concepts such as coordination and subordination, or scaling and variety ([4]). Changes in the system and its environment always preserve the system-environment complementarity. Now the question is whether it is possible to perceive changes where the adjoint relation between levels of organization is not preserved. This class of problems will be generally called design problems. The idea would be to 'push' the system 'far for the adjoint relation' and explore abstractions that underline these capacities and organizations.

In order to fix these ideas, the complementary relation between sets and monoids is analyzed. In particular, a monoid structure is represented in a type of one dimensional cellular automata space. The objects of the structure are realized by natural numbers, whereas the morphisms are realized by mappings between natural numbers. By enabling the state of a cell to play both the role of an object and a morphism between neighbour cells, the operation of composition and coupling is introduced. The paper demonstrates the formation of cells that work as boundaries between inner and outer areas by means of composition and coupling that are not structural preserving. Based on this model, a definition of the design capacity of systems is discussed.

To sum up, the paper identifies the concept of design as a distinct research question in complexity research. It explicitly links general problems of complexity with the specific concept of design and discusses the unique characteristics of design problems. It is hoped that this can be of benefit for both complexity research and design science.

References

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