Is it About Time to Investigate a Transdisciplinary Understanding of Design?

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Abstract. *This paper claims that now the time is right to investigate a transdisciplinary understanding of design. Nowadays, design is excellent in many disciplines and specialized fields but not connected and coordinated to other fields. The benefit of a transdiciplinary understanding of design will open up new ways in teaching, research and business. The current activities in this field at leading schools worldwide evidence that the time has come to gain a fundamental understanding of design.*
In this paper we describe the phenomena that design as a research topic currently gains in importance. We then discuss why there is no unified definition of design. We explain our approach towards a transdiciplinary understanding of design and show how this differs from other initiatives.
Keywords: *Design Science; Design; Modeling; Verification; Knowledge Visualization.*

Introduction: Why does a transdisciplinary understanding of design not yet exist?

Even though design is as old as the human race itself and is eminent throughout different disciplines the concept design is vaguely defined and its understanding diverges substantially.

Modeling, design, and verification are key steps in different disciplines of science, engineering, management, and architecture. However, within these fields the way they are understood and performed differs significantly. Design research, including design methodologies, tend to be based on expertise and formulated in terminology specific to a discipline, rather than from first principles. Design is typically concerned with creating things that people want. Since the initial brain work remains usually unseen to the outside, design is also mostly seen as a procedure related to material things. According to S. A. Gregory the fundamental idea behind design is building a structure, pattern, or system within a situation (Gregory, 1966). Engineering design is goal oriented and concerned with the process of making artifacts and complex systems for expert use. In natural science design abides mainly by the laws of nature. However, engineers, technologists, scientists as well as architects, artists, and poets are involved in design processes. These processes are more or less creative and imply a strong thinking ahead component.

Even though research on design can be traced back to the early 1960s it needs extensive research more than ever. One goal of further research would be to investigate such a systematic, integrated, and fundamental understanding of design as it presents itself across disciplines. For example, there is system design in engineering, algorithm design in computer science, process design in management, creative design in architecture, and self-organizational design in biology.

Design Science should yield a systematic approach towards finding appropriate design methods, where a design method is a pattern of work which is independent of the discipline and offers a way for solving problems.

Related Work: The Big Picture is Still Missing

Research on design has its origin perhaps in the recognition by Viollet-le-Duc in 1872. He stated that design problems are becoming too complex so that the designer's intuitive grasp is not enough to solve them sufficiently (Heath, 1984). Almost a hundred years later the disciplines of urban design, graphic and interior design, industrial design, and engineering recognized what nowadays is commonly understood as design.

Regarding design and science there are two periods of special interest: The 1920s with their investigations on scientific design products, and the 1960s with their research on scientific design processes. As a matter of fact already in the 1920s Theo van Doesbug and Le Corbusier had the desire to bring science and design together (van Doesberg 1923, Le Corbusier 1923). Both produced works based on the values of science: objectivity and rationality. The investigation of novel design methods has its origins in the upcoming problems of the 2nd World War. Novel, scientific, and computational methods have been investigated and applied to new and pressing problems.

In the 1960s the disciplines of urban design, graphic and interior design, industrial design, and engineering recognized what nowadays is commonly understood as design and became a discipline in its own right. The upsurge of initiatives during that decade testify to this quickly growing awareness: the Conference on Design Method in 1962 Jones, 1963), Christopher Alexander's PhD on the use of information theory in design in 1964 (Alexander, 1964), the Teaching of Design - Design Methods in Architecture conference in Ulm at the Hochschule für Gestaltung in 1966, the creation of the Design Methods Group at the University of California, Berkeley, in 1967, and of the International Conference on Engineering Design by Hubka as well as The Design Methods in Architecture Symposium in Portsmouth (Broadbent, 1969) in the same year. Buckminster Fuller was probably the first to coin the term Design Science. It was adopted by S. A. Gregory in 1965 at the conference on The Design Method (Gregory, 1966). Gregory defined Design Science as the study of design in theory and in practice, in order to gain knowledge about design processes, about design procedures to create material objects, and about the behavior of its creators.

Design methods, together with artificial intelligence, got another impetus in the 1980s. During that decade and also in early 1990s a series of books on engineering design methods and methodologies and new journals on design research, theory, and methodology were released. To name some of them: Design Studies (1979), Design Issues (1984), Journal of Engineering Design (1990), Languages of Design (1993), and Design Journal (1997). The most relevant and important design methodologists were Morris Asimow, John Christopher Jones, Nigel Cross, L. Bruce Acher, T.T. Woodson, Stuart Pugh, and David Ullman. The first generation of these methodologists wanted to find rational criteria for optimal decision making by incorporating scientific techniques and knowledge into the design process (Cross, 1984). As a member of the second generation and influenced by the philosopher Karl Popper, Horst Rittel proposed problem identification methods that explicitly include the identification and involvement of users. On the whole, these developments did not have a substantial practical impact. All too often, Artificial Intelligence was preoccupied with an idealized, noiseless world. In need for practical solutions, design became heavily application-driven. For specific engineering disciplines, such as user interface design, there already exist handbooks with detailed guidelines and best practices. By the lack of an overarching and practically applicable approach, different disciplines went off to develop and embrace more systematic design principles of their own.

Renaissance in Design Science: A Holistic Understanding of Design

Design Science is a systematic approach with the intention to find an appropriate design method. The term 'Design Science' became its recognition in the 1960s and was probably first used by the technologist Buckminster Fuller. It was adapted by S. A. Gregory in 1965 at the conference on The Design Method. Gregory defined Design Science as the study of design in theory and in practice, in order to gain knowledge about design processes, about design procedures to create material objects, and about the behavior of its creators. According to him, design is a process which has an input and an output. In 1967 Hubka established the International Conference on Engineering Design where he introduced their scientific approach to engineering design methods as Design Science for the first time. They described Design Science as a system consisting of logically related knowledge. This system should be able to organize the gained knowledge upon designing (Hubka, 1996).

A holistic understanding of design would still be a major step forward, as it would widen the gamut of methods and ideas that could be applied to any individual field, and as it would better support the construction of large-scale systems, with components now designed largely independently. Probably the most effective efforts in that direction still were those in the 1940s, in order to drastically improve the efficiency in manufacturing as part of the war effort. Multidisciplinary teams consisting of engineers, industrial designers, psychologists, and statisticians were set up, and had a noticeable impact on industrial output.

Moreover, design is still mostly seen as a procedure related to material things. However, the creative processes in the designer's head, with a lot of thinking ahead and what-if reasoning involved, remain largely undocumented and unaccounted for. In order to effectively support designers or to even go down the road of automated design, strong models about the systems and processes to be designed are required. These models have to include rich, semantic concepts about the global context of the problem and the intricate interdependencies that are at play. Therefore, future research should aim at reintroducing the strongly interdisciplinary aspect from the 1940s.

Goals and Research Fields

The potential lies in the advantageously importation of design methods from one domain to another one. We believe that this will help developing non-reductive approaches which contribute to manage the complexity of a given problem. One of the exciting and rewarding challenges will be to incorporate principles of natural design into human design processes. The fundamentals and principles of design in nature, which underlie some of the most complex and effective structures, are relatively little understood. They offer a largely unexplored repertoire of approaches to the design of man-made, elaborate systems. Both natural and human design have to be studied in a parallel effort, in order to detect such opportunities. Therefore, the translation of natural design principles into terms that other disciplines can work with will be a major research field.

There is an overarching, basic philosophical issue to be considered. Different disciplines may use the same terminology, but does it have the same meaning? Moving about in such highly interdisciplinary context, one should be aware of possible differences in the interpretation of even the most essential words. We found out that Knowledge Visualization helps to improve the communication among different disciplines. Knowledge Visualization supports finding visualization forms which work across disciplines and allow transferring facts, insights, experiences, attitudes, values, expectations, perspectives, opinions, and predictions. Visual representations improve the transfer and creation of knowledge between the different research groups. Since the notion of design differs significantly across domains it is important to recognize general principles and to establish guidelines and laws.

It is our belief that a holistic understanding of design has the potential to significantly change the way we do science in the future. By learning and understanding what design means in natural science, engineering disciplines, and management science, and adopting these insights to the respective other disciplines, we can investigate novel principles of design. As true believers, it is our goal to convey the opportunities and benefits of a holistic design concept, to evaluate the current understandings of design, and identify challenges and concerns. Therefore, we are going to publish a book The Design of Material, Organisms and Minds presenting various uses of design from design of the inorganic, design of organisms as well as design of products to design of the minds. This book will address design to gain a deeper understanding of design across various disciplines to support Design Science as a discipline that integrates the vast amount of isolated knowledge sources.

What We Do

At the Competence Center for Digital Design & Modeling at ETH Zurich (CC-DDM) we are bringing together different schools of thinking to establish a Design and Modeling Science. Therefore, we aim at this very interdisciplinary study of design methods, and this strongly linked with state-of-the-art modeling and verification paradigms. The focus is on uncovering domain independent principles and methodologies underlying successful design.

In order to arrive at this ambiguous goal we want to construct three pillars: research, training, dissemination. Teaching and dissemination have to be grounded in high-quality research. This is all the more the case here, as we target largely uncharted terrain. For this series of projects, topics have been selected in a way as to cover both biological and man-made designs. After extensive internal discussions, workshops, and colloquia the structure of cities has been chosen as our focal point. We will study their largely static substrate as well as the dynamic processes that are at play in that context. Modeling work will extract the necessary data in order to analyze and find the underlying structures. In turn, designs should then best make such structures explicit in their rule sets. Design can subsequently help to explain, construct, or alter particular instantiations of the structures under investigation. Given the high complexity and large-scale nature of both cases it will also be crucial to develop novel ways of visualizing the structures and processes. Creatively presenting data adds to the effectiveness, by which designs can be understood, adapted, applied, and communicated, but most of all, verified. These three layers – modeling / design / verification – form the backbone of our research.

We hope that we are thereby shaping a new generation of design methodologists. The ambition is to offer PhD students the interdisciplinary backing of the 1940s, as well as a pole position in the related domains of application, where we have chosen topics where ETH defines the international state-of-the-art. In particular, it has become possible to infuse the necessary, semantic level of computer processing for these domains.

Linkage to Architecture and CAAD

"Design is an activity that, in a complex, computerized society such as the one that we are entering now, calls for appropriate technical skills, creativity, and an attentive eye for aesthetic values, but also a marked ability to ponder the relationship between humanism and the world. This is the new human frontier: designing complexity." Augusto Morello

Charles Eamse described design which is a method of action as a plan for arranging elements in order to accomplish a particular purpose. Already in 1969 Charles Eamse raised the question "What is Design?" within the exhibition 'Qu'est-ce Que Le Design' at the Musée des Arts Décoratifs in Paris. Figure 1 illustrates Eames concept of the design process which is a system where the interests and concerns of the designer, of clients, and of society are interrelated. The design process would be successful when the concerns of all parties involved are served simultaneously. Figure 2 illustrates that the designer's mind is embedded in its environment with which she exchanges information, in her mind. The designed object O is shape by design decisions D that are divided into controlled decisions by the creator (d-variables) and context related decisions (p-variables). Both the design decisions as well as the context determine the performance of the object (P). These are only two brief examples showing that design is not the privilege of any particular profession and that namable researcher already thought about an interdisciplinary approach to design.

Architects are trained to face complex tasks and considerations that are too complex to grasp as a whole. Therefore, they are capable of structuring information, thinking in networks and representing concepts, and to represent complex interrelations. Moreover, by the nature of the architectural discipline which bridges basic science and engineering, many architects have the ability to merge rational

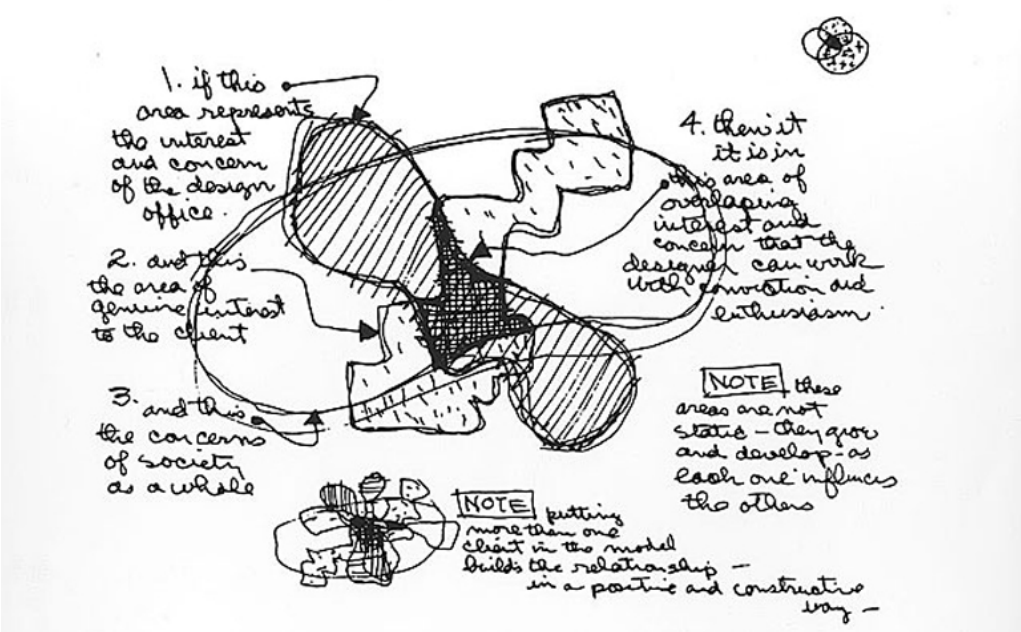

Figure 1
Diagram by Charles Eames, displayed in the 1969 Exhibition Qu'est-ce Que Le Design?(What is Design?),at the Musée des Arts Décoratifs in Paris, photograph.(Image source http://www.loc.gov/exhibits/eames/bio.html)

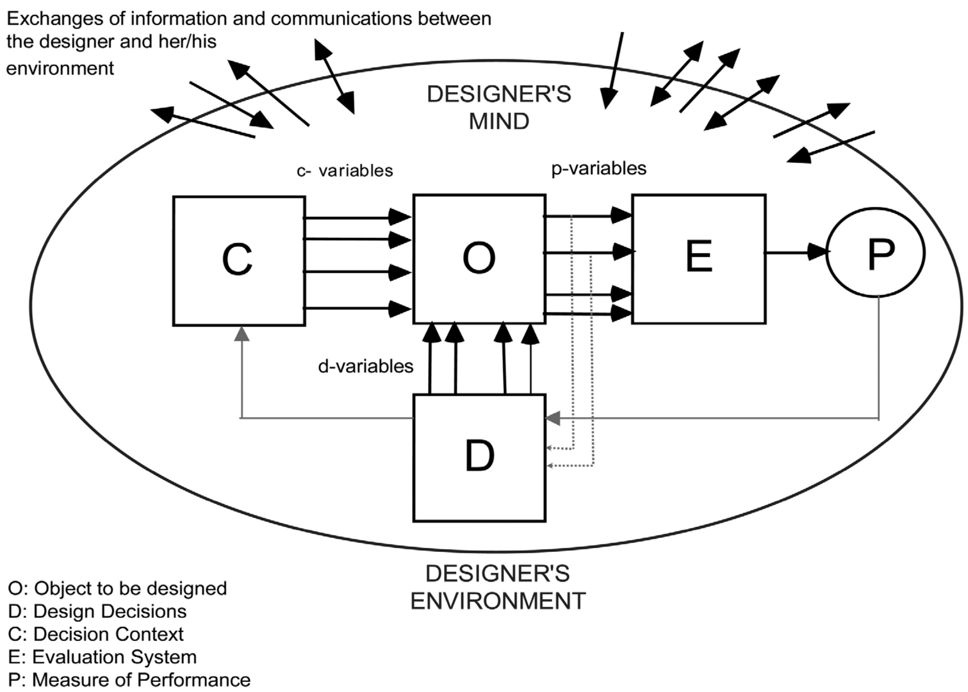

Figure 2
The following picture, which is indebted to the idea of open systems as first articulated by Ludwig von Bertalanffy in the 1930's and to Norbert Wiener and Ross Ashby's cybernetics and the notion of feedback loops in the 1940's, proved to be a useful tool towards the elaboration of more explicit approaches to design.(Image source Jean-Pierre Protzen)

and quantifiable parameters as well as more intermediate and uncertain variables. For proper building design and execution architects take knowledge of other disciplines into account, have close cooperation with a diversity of specialists, and need a high degree of organizational competence. Given all this it does not come to a big surprise that architects who do research on design since the establishment of the discipline are now starting to think of a transdiciplinary understanding on design.

In Lang (2006) we discussed how architects' skills, which bring different demands together, can be used in combination with research findings from other disciplines for the design of complex systems based on fruitful teamwork. Within the next step we were searching for application areas that will be strengthened through an interdisciplinary design approach. Therefore, we have chosen future cities, an important area both in fast evolution and in great demand as one application domain within the CC- DDM. This includes the 3D modeling and design of architecture and more importantly, of entire cities and their surroundings. With Google Earth and similar initiatives, with a growing interest in detailed surveying from public authorities and utility suppliers, with a tendency towards 3D navigation support, with higher visual quality in virtual sets in movies and games, and with the emergence of cyber-communities like SecondLife, it goes without saying that technologies to quickly build detailed 3D city models are growing in importance. With problems of mobility and the environment on the rise, there is an urgent need to design sustainable cities. Here we couple state-of-the-art modeling with the opportunities that they entail for design. The creation of more intelligent tools, rather than ever more detailed data capture,

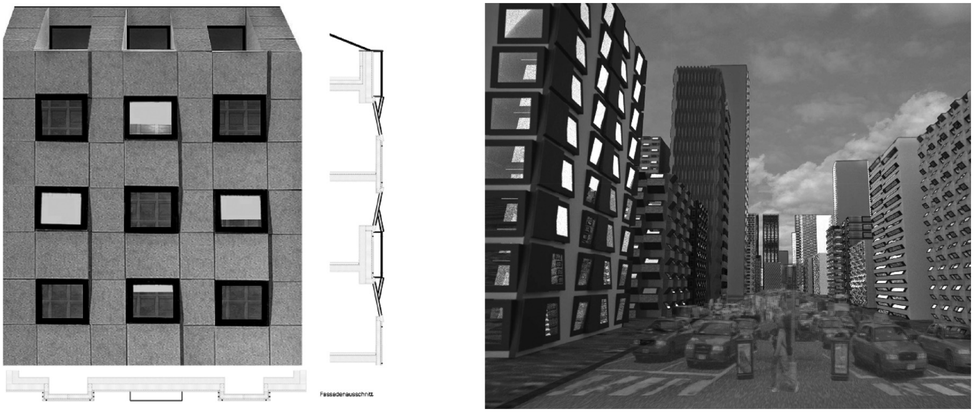

Figure 3Original façade design by an architecture student (left image) and rendering of a large-scale urban environment with different façade variations based on the original façade using the framework developed by Halatsch. (Image source Halatsch, 2008)

should ensure that the quickly raising demands on precision and realism can be met, and this also more automatically. For a more comprehensive description and more details we refer to Lang (2007).

As a starting project the Chair of Information Architecture (Department of Architecture) and the Computer Vision Laboratory (Department Electrical Engineering and Information Technology), both members of the CC-DDM use procedural modeling methods to automatically derive 3D city models. The Computer Vision Lab at ETH Zurich has developed shape grammars for procedural modeling which exploit the regularity presented in many buildings (Müller, 2006). Grammar guided modeling is used to produce a model of a building based on images. Applying set of rules which exploits the regularity presented in many buildings and the semantic labeling of same elements like windows and doors have a dramatic effect on the visual quality. These rules are also used to clean up the data and fill in missing parts coming from images which contain occlusions like trees, cars or people (Müller, 2007). This

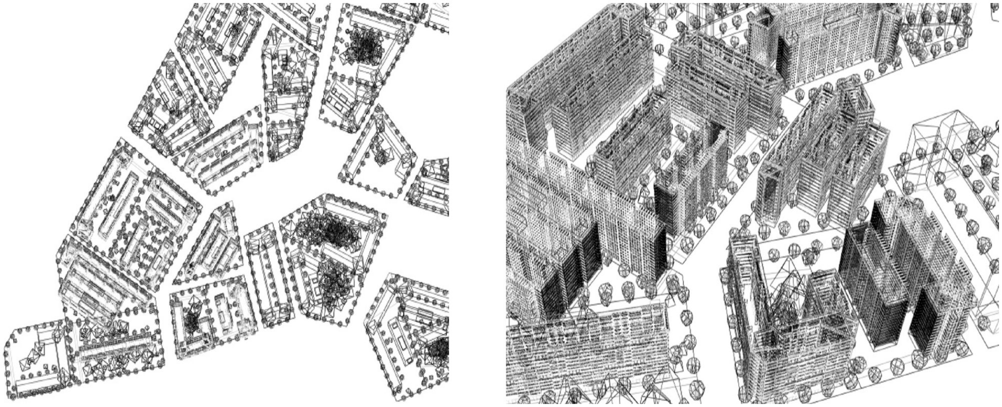

Figure 4
Synthetic urban environment of Pungol using CGA shape grammars produced by the framework developed by Halatsch. (Image source Halatsch, 2008)

grammar-based approach could be of great help for planning future cities taking into account long-term ecologically factors. Within this joint project both research groups combine their knowledge with the goal to explore how shape grammars can be integrated into the urban design process. CGA shape grammar, a novel shape grammar for the procedural modeling of computer graphics architecture, is extended for encoding urban open spaces. Using this novel framework architects can easily generate and visualize large urban scenarios containing high resolution buildings as well as vegetation geometry. This framework was tested within a student course at the Chair of Information Architecture (see Figure 3) and used for the district of Pungol in Singapore (see Figure 4). These two case studies proofed that this framework makes a contribution for master planning and that it can be successfully integrated in the architecture curriculum. The next step will be the integration of dynamics such as airflow, shading, movement of people, traffic flows etc. Ongoing projects are the pattern-based procedural design of Science City ETH's open spaces and the challenging planning of high density Housing in Singapore. For further details on the project please read Halatsch (2008).

Conclusion

Our mission statement begs the fundamental question whether one can find a common theory underlying design and modeling. There still is a profound lack of interdisciplinary research on these issues. The same words are not even guaranteed to carry the same meaning as soon as one crosses over to other disciplines. Therefore, related synergies between disciplines remain largely unexplored and unexploited. Today, the concepts of modeling and especially design are vaguely defined and ways of approaching them diverge substantially.

As described the goal within the CC-DDM is to set up an interdisciplinary program of research, but sufficiently connected to relevant, practical cases. The long-term goal is to arrive at a crossdisciplinary theory of design, leading to more efficient, more economic, and more satisfying (in the sense of aesthetics and functionality) designs.

This paper claims that it is now time to establish a transdiciplinary understanding of design to overcome the situation where research on design in specialized fields is excellent but not connected and coordinated to other fields. The benefit of a transdiciplinary understanding of design is the strengthening of Design Science, thus having more impact in teaching, research and business. The establishment of interdisciplinary design centers and schools such as the d.school at Stanford University, the master of Design Science at the University of Sydney, the Design Research Conference organized by the IIT Institute of Design show that interdisciplinary teams are gaining in importance. This indicates that research on design, especially design as a scientific discipline is gaining in importance.

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