1. Domains of Design Research

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1.1 Introduction

The goal of this short paper is to invoke a discussion of fundamental principles of design thinking, allowing us gaining insight into the nature of design as an innate human faculty.

We can find every kind of lines for the comparison between different design disciplines, their approaches and unfolding phenomena of design events in time. In addition we notice that approaches are markedly complementary. In the early days of design research Broadbent noted that all design processes are based on scientific methods. Therefore the aim was to devise rationalised procedures or rules analogous to the mathematical expressions that are sets of instructions for solving design problems. Popper noted that we cannot expect profound truth from methodology, but it may help us to clarify the logical situation and even to solve some far-reaching problems. Design science according to Hubka and Eder is understood as system of logically related knowledge, which should contain and organise the complete knowledge about and for designing. The (design) science requires systematic descriptions (declarative knowledge and descriptive statements), which belong in the area of theory, methodology and instructions for the practical (design) activity (procedural or prescriptive knowledge), and/or (deterministic and flexible) algorithms and techniques for part processes and operations. Archer has introduced boundaries of attention in design research through identifying the following ten areas of the whole field of design (science): design history, design taxonomy, design technology, design praxeology, design modelling, design metrology, design axiology, design philosophy, design epistemology and design pedagogy. Perhaps we can add the following additional areas: design management, design policy, design aesthetics, design semantics, design decision-making, design evaluation, design logic, design ontology, design logistics, design syntax, design ethics and design informatics. This prompts us to seek and define a general framework or classification for these areas. In this regard we recognise the following three major categories:

- Areas that define the agents of design and can describe the study of creative and cognitive activities of design;

- Areas that define the influences of design in terms of studying both internal and external experiences of designing; and

- Areas that define the operations of design in terms of studying the organisation and the product of designing.

We can argue that these discussions are relevant to all design disciplines. This paper will attempt to group together a coherent range of discussions to explore the design science. In this paper our attention will be on the design of the built environment (architecture, urban design, urban planning, civil engineering and policy analysis). On the other hand the emphasis and

accent of this paper will be on advanced technologies (applications of information, communication and computer technologies). These issues will distinguish the goal and objectives of this paper. The issues discussed will be complementary and will cover the entire spectrum of design science in the light of the applications of the information, communication and computer technologies.

Our goal in this paper is to create a platform for introducing and the exchange of ideas and experiences related to the study and application of advanced technologies to fields of designing the built environment. Further we discuss terms and conditions for introducing new tools (offered by the latest developments in the fields of artificial intelligence, robotics, image processing and information technology) and new strategies (required by the inevitable changes of the professional and educational working environments of architecture, building engineering, civil engineering, urban design and urban planning). In this regard, relevant subjects and themes include but are not limited to domains of artificial intelligence, design support environments, decision support systems, knowledge representation, human and machine intelligence, image processing, building and construction robotics, computer vision (applications and components), machine training and learning systems, case-based reasoning systems, construction robotics, computer vision, intelligent design and planning tools, computer graphics, interactive virtual realities for design and planning of the built environment, intelligent CAD/ -CAM/ -CIM/ -GIS, design and planning informatics, geoinformatics, hydroinformatics, building informatics, etc. These can be divided into two major categories of the applications domains and the basic tools domains. Also, the studying and discussing issues related to design of the built environment in each area of the design science will occupy a central place in this paper. In this paper we can propose the following discussion which can provide an overview of possible design research domains.

1.2   The agents of design

These are the areas that define the agents of design and can describe the study of creative and cognitive activities of design.

1.2.1 Cognition

Cognition in design regards the faculty of knowing design knowledge and all activities related to design awareness. We can recognise the following areas to discuss in the context of cognition.

- Design philosophy. Design philosophy is the study of ways of design thinking. It is a search for general understanding of design values by chiefly speculative rather than observational means. It can be an analysis of the grounds and concepts expressing fundamental aspects of design. The design philosophy concerns the general theory underling the design thinking. It can describe the general beliefs, concepts and attitudes about design or designer.

- Design logics. The design logics are the study of principles of design reasoning and the underling foundations of the design thinking. It can describe the principles and criteria of design inference and demonstration. It can cover the arguments about the interrelation or sequence of design events when seen as inevitable or predictable.

- Design modelling. It is the study of cognitive models, externalisation and communication of design ideas.

- Design epistemology. It is the study of the nature and methods of knowing, feelings and beliefs regarding design (design knowledge theory).

- Design psychology. It is the study of mental processes and behavioural characteristics of individuals and groups influenced by the design activity or affected by the products of designing.
- Design syntaxis. It is the study of the system of rules and the structure of the design process (design grammar).

1.2.2 Creativity

Creativity in design concerns all processing activities of intelligent performance, which contribute to existence of design according to recognisable structures and syntactic rules. It relates to the learning and reasoning processes of designing and a starting point for perceiving design in mind for modelling an empirical existence.

- Design aesthetics. It is the study of a particular theory or conception of beauty in design. It deals with the nature of beauty and taste in design as well as the creation and appreciation of beauty in design regarding an approach to what is pleasing to the senses and especially to the sight.
- Design semantics. It is the study of meaning and intentions in design. It concerns the classification of changes in the significance of forms in the development of design. It is about innovative meanings to achieve a desired effect through design especially by the use of novel design factors.
- Design ontology. It is the study of the general characteristics and principles of the design process.

1.3 The influences of design

These are the areas that define the influences of design in terms of studying both internal and external experiences of designing.

1.3.1 Internal experiences

These are the observation of design facts and design events and are considered to be the source of design knowledge.

- Design history. It is the study and analysis of design cases with regards to reasons for designing as well as social, cultural, political and economic factors with their influence on the design cases.
- Design pedagogy. It is the study of principles, methods and techniques of teaching design.
- Design evaluation. It is the study of values and criteria for the evaluation and selection of design decisions and methods for comparing different courses of action during the design process.

1.3.2 External disciplines

These are the areas dealing with design facts and events as well as ways of producing design knowledge and acquiring design skills.

- Design axiology. It is the study of the nature, types, and criteria of values in design with emphasis on the relationship between technical, economic, moral, social and aesthetic values of design.
- Design policy. It is the study of a definite course or method of action selected from amongst alternatives and in the light of given conditions to guide and determine present

and future design decisions. It concerns a high level overall plan embracing the general design goals and acceptable design procedures.

- Design decision-making. It is the study of design statements and the ways design decisions are made as well as the principles of design decision-making and methods for arriving at decisions during the design process.
- Design ethics. It is the study of definitions and code of conduct for the design process including all moral, social, political, cultural and personal understandings, insights and norms.

1.4   The operations of design

These are the areas that define the operations of design in terms of studying the organisation and the product of designing.

1.4.1 Organisation of design

The organisation of design refers to a purposeful and systematic arrangement for the design activity.

- Design taxonomy. It is the study of the general principles for the classification of design as phenomena. It also concerns the orderly classification of designs and their relationships.
- Design praxeology. It is the study of the nature, organisation and the instrument of design.
- Design management. It is the study of the organisation of design. It concerns the act of conducting and supervising design, using design means to accomplish design ends.
- Design logistics. It is the study of all the activities required for the handling of the design process as well as the planning of these activities.

1.4.2 Product of design

The product of design is the result of design actions, operations or processes.

- Design technology. It is the study of the principles of scientific treatment of designs and their relationships as a system. It concerns using technical processes, methods or knowledge for designing.
- Design metrology. It is the study of the qualitative aspects of measurement and weight systems regarding design.
- Design informatics. Seen from a design point of view, it is the study of information about the design process, design in an information environment and the means of collection, organisation, classification, transformation, retrieval and use of design knowledge. It refers to the application of the information, communication and computer technologies to the design process.

1.5   The design application domains

The design application domain is the set of areas from the design science that use basic design tools to perform essential tasks that belong to those areas.

1.5.1 Design decision support systems

Design decision support systems are processing tools that developed to support decisions in design processes.

- Design support environments. Design support systems are processing tools developed to support the design activity.
- Intelligent design and planning tools. These are design and planning rules and tools devised with AI principles. They provide logical inferences and are specifiable by formal design and planning rules, content of the design and planning activity and how design and planning activity takes place.
- Interactive Virtual Realities for design and planning of the built environment. These are interactive AI-based tools for design and planning of the built environment.
- Intelligent CAD/ -CAM/ -CIM/ -GIS. These are necessary AI-based tools for design and engineering in an information environment. It involves the application of the information, computer and communication technologies to the areas of designing the built environment.

1.5.2 Design informatics disciplines

These disciplines are concerned with the study and application of methods for data processing using the information, communication and computer technologies.

- Design informatics. Seen from an informatics point of view it is the study of methods for processing design data using the information, communication and computer technologies.
- Planning informatics. It is the study of methods for processing planning data using the information, communication and computer technologies.
- Geoinformatics. It is the study of methods for processing geographical and geotechnical data using the information, communication and computer technologies.
- Hydroinformatics. It is the study of methods for processing hydraulic and hydrological data using the information, communication and computer technologies.
- Building informatics. It is the study of methods for processing building data using the information, communication and computer technologies.
- Construction robotics. It is the study of methods and techniques for performing building and constructions tasks by machines that perform monitoring tasks and use monitoring data for the execution of these tasks.

1.6   The basic design tools domain

The basic tools domain is the set of methods and tools from informatics science that can be used for the performance of design tasks.

1.6.1 The processing tools

Processing tools are methods and techniques for data processing tasks using the information, communication and computer technologies.

- Image processing. It is the study of methods for processing graphical data on computers. It refers to the recognition and structuring of design images in the context of the design activity.
- Computer vision (applications and components). It is the study of methods for processing real time graphical data on computers and the recognition and structuring of captured and real-time design.
- Computer graphics. It is the study of methods and techniques for graphic data representation in the design process.

1.6.2 Artificial intelligence tools

These tools concern methods and techniques for data processing in situations of high complexity and/or uncertainty and/or incomplete data.

- Knowledge representation. It is the study of methods for representation of design knowledge in a way that processing tools can use it.

- Human and machine intelligence. This is the area of studying the complex structure of knowledge concerning the design activity in an information environment.

- Machine training and learning systems. These are processing tools that use the design data, representing the state of a real design system to define its behaviour and performance

- Case-based reasoning systems. These are processing tools that use the design data, representing experiences of pervious design-cases to define their behaviour, outcome and performance.

The field of design research has yet to be explored fully. All discussions of fundamental principles of design thinking and the study of design from different points of views and a variety of contexts will help understanding design as a unique innate faculty of humans. The author invites you to submit your comments, suggestions and views as notes or papers. These contributions will eventually form the basis for further discussion of Design Research Domains in a broader perspective.

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