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A GRASP OF STUDY CHARACTERISTICS OF DESIGN AND ENGINEERING DESIGN BASED ON MULTISPACE DESIGN MODEL

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ABSTRACT:

In recent years, as the problems in design and engineering design became complicated and indistinct, the possibility for the integrated design that comprehends design and engineering design is indicated. In this study, in building the integrated design, the comparison analysis of papers published in design system societies and in engineering system design societies based on the Multispace Design Model was carried out. As a result, in design system societies, value elements, meaning elements, and attribute elements are studied. On the other hand, in engineering design system societies, state elements and attribute elements are studied. In both societies, deduction is studied. In addition, from the characteristics grasp, in both societies, the study of the boundary setting and abduction are indicated as the issues.

KEYWORDS: DESIGN METHODOLOGY, THEORETICAL ISSUES, ENGINEERING DESIGN

1. INTRODUCTION

The creation of artifacts can be divided into design and engineering design. In design, the objects and their surrounding products and occasion are paid attention to. On the other hand, in engineering design, the objects themselves are paid attention to. In addition, design system societies study problems related to design while engineering design system societies study problems related to engineering design. Design and engineering design had been considered different in quality. However, as the problems in design and engineering design became complicated and indistinct, a symposium that comprehensively dealt with design study and engineering design study was held in Japan (Design symposium 2006 2006). For this reason, in recent years, the possibility for the integrated design that comprehends design and engineering design is indicated. It is necessary to grasp the characteristics of design and engineering design so that design and engineering design are reflected in the integrated design. Because the study is an act of gaining the knowledge required for the practice, the characteristics obtained from the study correspond with the characteristics of the practice. Therefore, it is necessary that the characteristics of design system societies and engineering design system societies are grasped. Moreover, along with the grasp of characteristics, the study issues from the few studied fields help the development of design and engineering design. As a result, the characteristics and study issues of design study and engineering design study are important knowledge in building the integrated design. The comparison analysis of design system societies and engineering system societies is one of the methods to grasp the characteristics; however, this theme has not been studied well.

Consequently, the objective of this study is to grasp the study characteristics and study issues from the comparison analysis of design system societies and engineering design system societies. Firstly, study objects of design system societies and engineering design system societies are extracted from papers published in design system societies and engineering design system societies. Secondly, the study characteristics of design system societies and engineering design system societies are grasped from the comparison of study objects. Finally, study issues are indicated in consideration of the grasp of study characteristics. In this study, the Multispace Design Model was paid attention to as a view point that compared the study objects of design system societies and engineering design system societies.

2. THE MULTISPACE DESIGN MODEL

The Multispace Design Model, as shown in (Fig.1), is a model that has an ability to describe design and engineering design (Yoshiyuki Matsuoka 2005). This model consists of thinking space where elements related to the object and reasoning are described, knowledge space where knowledge used for reasoning is described, and relative system surrounding thinking space and knowledge space.

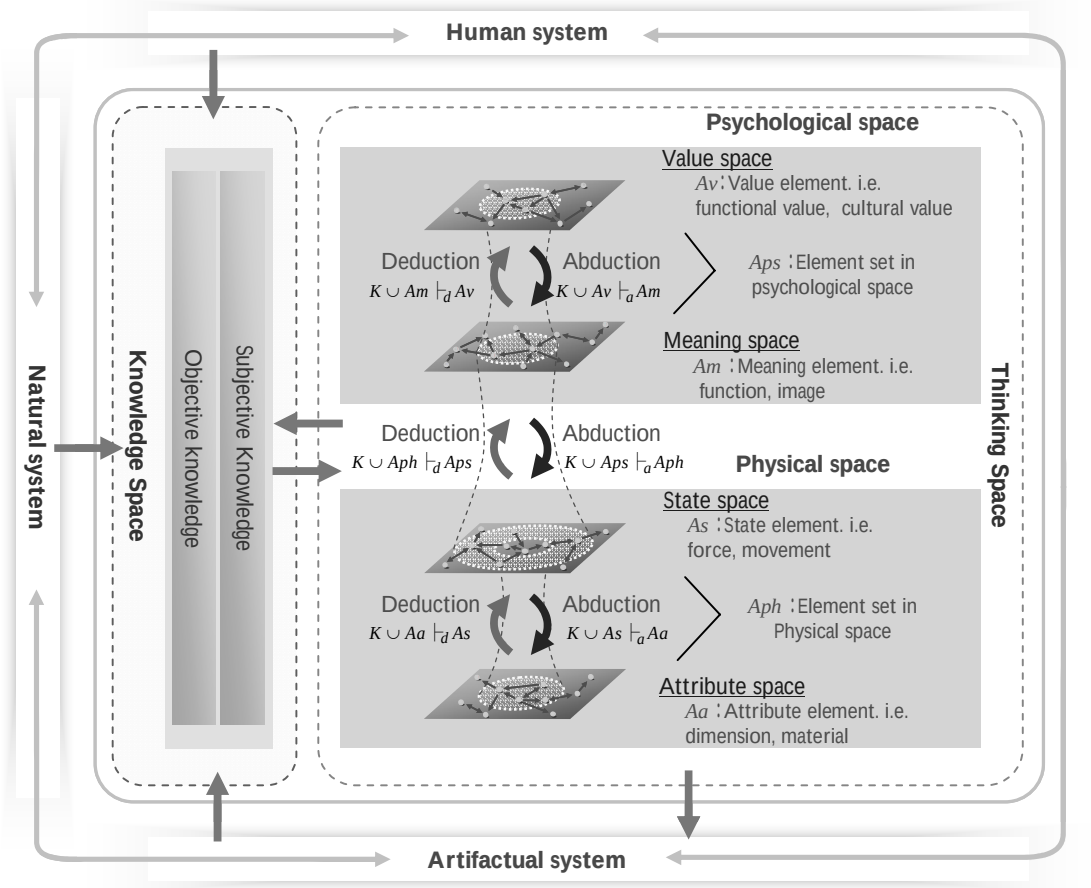

Figure 1: Multispace Design Model

2. 1. THINKING SPACE

Thinking space consists of the value space, the meaning space, the state space, and the attribute space. The value space consists of elements that describe cultural value and functional value, and the relationship between these elements. The meaning space consists of elements that describe function and image, and the relationship between these elements. The state space consists of elements that describe physical quantity generated when the object is in a condition, elements that describe a condition, and the relationship between these elements. The condition is the system that consists of supposed elements excluding elements consisted of object. The condition consists of time elements, spatial elements including gravitational field and magnetic field, and human elements that describe bodily and physiological property including body height and eye motion. The attribute space consists of elements that describe geometrical and physical property including dimension and material like being shown in the technical drawing. The psychological space that describes psychological elements of the object consists of the value space and the meaning space. The physical space that describes physical elements of the object consists of the state space and the attribute space.

2. 2. REASONING

Modeling in space and modeling between spaces are acts that model elements relation in thinking space. Modeling in space is an act that builds relation models of elements in the same space. Modeling in space consists of grasp of elements relation and boundary setting. The former describes a grasp of supposed elements in the same space and grasp of relation in these elements. The latter describes a setting boundary of object domain toward the elements that exists innumerably in the same space. In design and engineering design, to set a boundary shows that supposed elements becomes clear.

On the other hand, modeling between spaces is an act that builds relation models of elements in the different spaces. Models built by modeling between spaces are used for deduction and abduction. The deduction is reasoning used to derive lower space elements from upper space elements. In contract, the abduction is reasoning used to derive upper space elements from lower space elements. For example, the former is reasoning used when someone generates an image from configurations and colors. In contrast, the latter is reasoning when someone derives configurations and colors that generates the image.

Where K is knowledge, Av is value space elements, Am is meaning space elements, As is state space elements, Aa is attribute space elements, Aph is elements in physical space, Aps is elements in psychological space, d is reasoning rule in deduction, and a is reasoning rule in abduction. The reasoning is expressed as follows.

Deduction from meaning space to value space	$K \cup Am \vdash_d Av$	(1)
Deduction from physical space to psychological space	$K \cup Aph \vdash_d Aps$	(2)
Deduction from attribute space to state space	$K \cup Aa \vdash_d As$	(3)
Abduction from value space to meaning space	$K \cup Av \vdash_a Am$	(4)
Abduction from psychological space to physical space	$K \cup Aps \vdash_a Aph$	(5)
Abduction from state space to attribute space	$K \cup As \vdash_a Aa$	(6)

2.3. Position of Design and Engineering Design

The studies on thought experiment and processes in design and engineering design show the characteristics of design and engineering design as follows (LEE W 1995).

The characteristic of design is that objective and constraint condition are often indistinct. Therefore, objective becomes clear in consideration of psychological elements including demands of users and social

trend. At the same time, in consideration of physical elements including configurations and color, diverse solution candidates to the indistinct objective. Then the solutions are derived by evaluation of solution candidates. As a result, in design, the psychological elements relations are mainly paid attention to. In addition, diverse solutions are derived in interactive consideration of elements.

On the other hand, the characteristic of engineering design is that objective and constraint condition including function and performance are often clear. Therefore, the solutions are derived in consideration of physical elements, including mechanisms and materials, to perform the function. Particularly, in case the problems can be quantified, optimum solutions are derived with optimization approach. As a result, in engineering design, the relations of physical elements are mainly paid attention to. In addition, optimum solutions including configurations and setting angles are derived in unidirectional consideration of elements.

Compared design with engineering design, the characteristics of design are strongly described in the early process of product development while the characteristics of engineering design are strongly described in the late process of product development. Here, the characteristics of processes in design and engineering design are described as shown in (Fig.2) with the Multispace Design Model. In the early process of product development, design that interactively deals with psychological elements and physical elements is described. On the other hand, in the late process of product development, engineering design that unidirectionally deals with physical elements is described. For this reason, the elements paid attention to and the methodological characteristics in design and engineering design are comprehensively described with the Multispace Design Model. Therefore, it is possible that the comprehensive comparison analysis of study object in both societies is carried out by the Multispace Design Model.

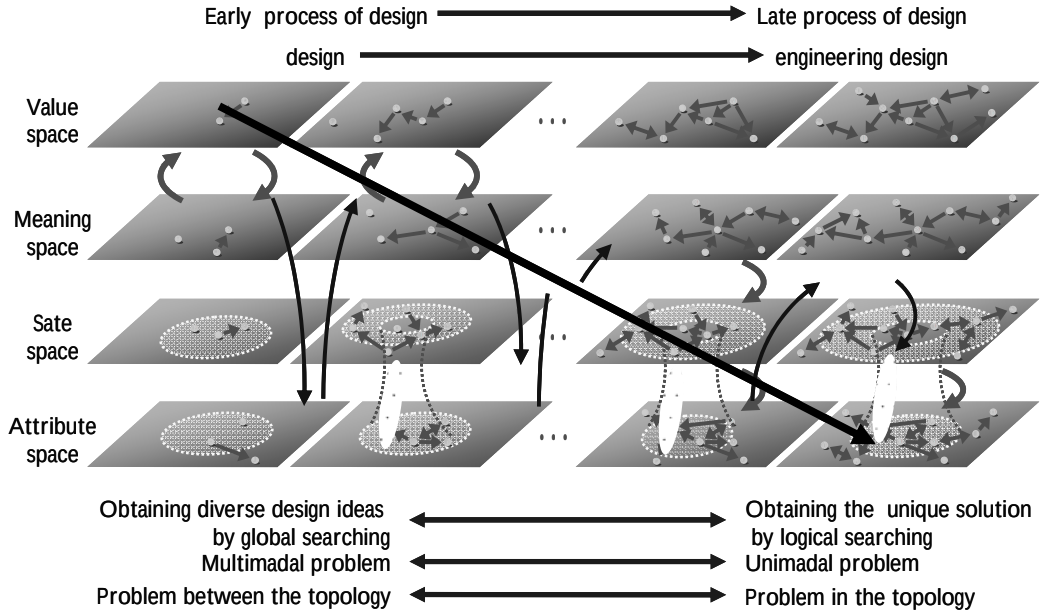

Figure 2: Position of design and engineering design

3. Comparison Analysis

3.1. Analysis Object, Analysis Method, and Analysis Conclusion

Analysis objects are the papers that are published for the past ten years (from 1996 to 2005, the total is 1353) in design system societies and engineering design system societies. In this study, JAPANESE SOCIETY FOR THE SCIENCE OF DESIGN (JSSD) represents design system societies, and the papers (440 in total) published in the Bulletin of Japanese Society for the Science of Design, a collected papers of JSSD, are the analysis objects of design system societies. On the other hand, Japan Society for Design Engineering (JSSD) and The Japan Society of Mechanical Engineers (JSME) represent engineering design societies, and the papers (284 in total) published in the Journal of Japanese Society for Design Engineering, a collected papers of JSSD, and the papers (629 in total) of Transactions of the Japan Society of Mechanical Engineers, a collect papers of JSME, are the analysis objects of engineering design system societies. Reasoning in the Multispace Design Model was used for classification items, the result, as shown in (Table.1), was obtained. In addition, from the comparison analysis of the result, the characteristics are grasped as shown (Fig.3) and (Fig.4).

Table 1: Result of analysis

Location of Multispace Design Model				Design system societies(440)		Engineering Design system societies(913)	
				Number of cases	Percentage (%)	Number of cases	Percentage (%)
Thinking space	Modeling in space	Grasp of elements relation	Value space	82	18.6	22	2.4
			Meaning space	353	80.2	285	31.2
			State space	130	29.5	763	83.5
			Attribute space	324	73.6	853	93.4
		Boundary setting	Value space	—	—	—	—
			Meaning space	3	0.7	3	0.3
			State space	2	0.5	6	0.7
			Attribute space	4	0.9	5	0.5
	Modeling between spaces	Deduction	Value and Meaning space	17	3.9	3	0.3
		Abduction		5	1.1	2	0.2
		Deduction	Value and State space	9	2.7	5	0.5
		Abduction		3	0.7	3	0.3
		Deduction	Value and Attribute space	38	8.6	11	1.2
		Abduction		6	1.4	6	0.7
		Deduction	Meaning and State space	42	9.5	60	6.6
		Abduction		9	2.0	10	1.1
		Deduction	Meaning and Attribute space	136	30.9	67	7.3
		Abduction		25	5.7	24	2.6
		Deduction	State and Attibute space	63	14.3	662	72.5
		Abduction		16	3.6	176	19.3

Many studies Few studies

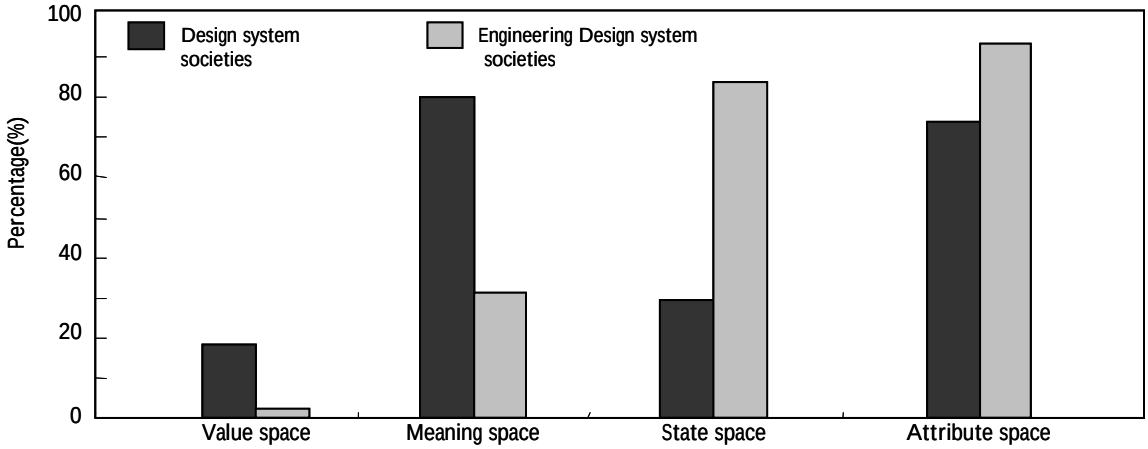

Figure 3: Comparison of grasp of elements relation

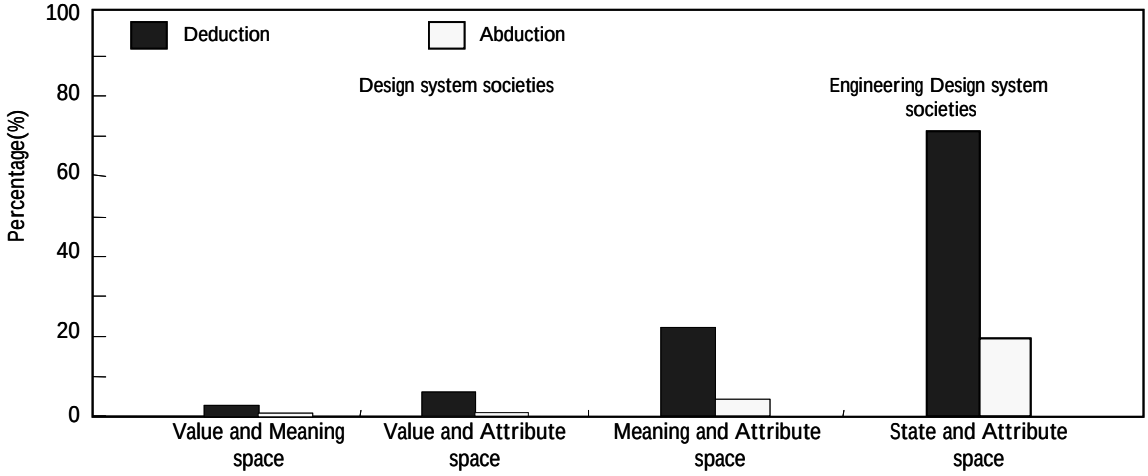

Figure 4: Comparison of deduction and abduction

4. A Grasp of Characteristics and Problems Extraction by Comparison Analysis

4.1. The Characteristics Study Objects in Design System Societies

As indicated in (Fig.3) and (Fig.4), the characteristic studies of design system societies are the studies on grasp of elements relation in the value space, the meaning space, and the attribute space, and deduction of these elements. In design, as indicated in section 2.3., designers often derive solutions including figures and colors from the unclear objective including values and images based on their sensitivity. Therefore, in design system societies, study objects mentioned above are characteristically treated. In addition, derivation processes of solutions are considered as a method to solve the inverse problem using an inverse reasoning. Repeating deduction after setting a constraint condition is also the methods to solve the inverse problem. It is known that the former method is more difficult than the latter method (Yoshiyuki Matsuoka

2005). Therefore, in design system societies, deduction is mainly studied. For this reason, in design system societies, the studies for obtaining the guidelines that describe images from the relation of attribute elements including configurations and colors are mainly carried out (TSAI P-J 2002, KOSTOV M 2001, WOO H R 2001).

4.2. The Characteristics Study Objects in Engineering Design System Societies

As indicated in (Fig.3) and (Fig.4), the characteristic studies of engineering design system societies are the studies on grasp of elements relation in the state space and the attribute space, and deduction of these elements. In engineering design, as indicated in section 2.3., objectives including function and performance are often clear. Firstly, functions are corresponded with the physics phenomenon so that the physics phenomenon is modeled. Secondly, objective function and constraint condition that properly described functions are determined. Finally, solutions including configurations and structures are derived based on optimization approach. Therefore, in engineering design system societies, study objects mentioned above are characteristically treated. In addition, same as the design system societies, deduction is mainly studied. For this reason, in engineering design system societies, the studies for clarifying physics phenomenon that corresponds with the functions are mainly carried out (Seiji Watanabe and Takashi Yumura 2005, Naoki Kobayashi and Masao Ikeda 2003).

4.3. Study Issues

4.3.1. Study Issues of Design System Societies

As indicated in (Fig.3), few studies related to the state space elements have been made in design system societies. In design system societies, as indicated in section 4.1., the study related to the configurations and colors, and the images of the object is often carried out. However, how the object is seen in a light and the luster on the surface of the object according to the light are important causes that affect the images. Elements that describe physical quantity are elements of the state space. The problem in dealing with elements of the state space is that the objects are often affected by human and environment. Because the object affected by human and environment often have characteristics of nonstationary, nonlinear, and plastic, it is difficult to study the elements of state space according to the constant boundary conditions as the objects studied in natural science. Therefore, few studies on the state space elements have been made in design system societies. However, in recent years, because computational engineering and cognitive science are developing, to the objects mentioned above, it is possible to study the state space elements according to the constant boundary condition. In the study of the state space elements, the relations between the state elements and the attribute elements affected by the human and the condition are systemized. From these studies, new indicators that describe the image are obtained. For this reason, in design system societies, the study related to the state space elements is indicated as the future study issues.

4.3.2. Study Issues of Engineering Design Societies

As indicated in (Fig.3), few studies related to the value space elements and the meaning space elements have been made in engineering design system societies. In engineering design system societies, as indicated in section 4.2., the study related to the physics phenomenon that describes the object function is carried out. In such a study, psychological elements including the value space and the meaning space are already considered. Therefore, few studies on the value space elements and the meaning space elements have been made in engineering design system societies. In actual design, multiple objective problems that describe multiple functions are often considered. In these studies, derived solutions are pareto solutions when the relations of functions are tradeoff. Pareto solutions are the solutions that at least one other objective functions are deteriorated when the value of a certain objective functions is improved. In addition, because pareto solutions are multiple solution sets, it is necessary that the proper solution is selected. However, it is difficult only in the studies on a physical phenomenon of the function to judge which solution is proper. In this case, a unique solution is derived by evaluation index for the objective functions that describe functions. Evaluation index is the element of the state space in the Multispace Design Model. However, it is necessary that relations and superiorities of functions are considered when evaluation index is set. Relation and superiorities of functions are elements of the meaning space and the value space. Therefore, in the study of the value space elements and the meaning space elements, new indicators that select the solution in multiple objective problems are obtained. For this reason, in engineering design societies, the study related to the value space elements and the meaning space elements is indicated as future study issues.

4.3.3. Study Issues in Both Societies

As indicated in (Table.1) and (Fig.4), in design system societies and engineering design system societies, few studies related to boundary setting and abduction have been made. In design and engineering design, elements exist innumerably and relate mutually. Therefore, it is an important process that elements are selected as objects. Practically, elements are selected when designer and engineer are doing work. However, in designer and engineer, it is thought that selection of elements is not considered as boundary setting. Therefore, in both societies, few studies of boundary setting have been made. In the study of boundary setting, new indicators that determine the elements of object are obtained. An effective work is carried out by using the boundary setting to select the elements. In addition, idea generation of designer and engineer is often carried out by abduction. However, as shown in section 4.1., the studies of abduction are difficult. Therefore, in both societies, few studies of abduction have been made. In the study of abduction, new indicators that support idea generations are obtained. For this reason, in both societies, the study related to boundary setting and abduction is indicated as future study issues.

5. Conclusion

In this study, the study characteristics of design system societies and engineering design system societies are grasped from the comparison analysis of study objects in design system societies and engineering design system societies. Moreover, study issues of each societies and common study issues for both societies are indicated.

6. Acknowledge

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