Comparative Analysis of Thinking Process between Designer and Engineer Based on Case Application of Multi-Space Design Method

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Abstract

This paper describes each feature of thinking process for a designer and an engineer based on comparative analysis applying Multi-space Design method (M method) to the bench design. Additionally, it is indicated that a utility of M method for an unrestricted idea generation and precise design thinking.
M Method is a design method that combines idea generation and analysis methods based on the Multi-space Design Model, which is a framework to arrange elements used in design. Using the M method, user can derive precise design thinking. In addition, this method aims to correspond to various usages. In the past study, the usage for precise design thinking was confirmed thorough case application by a professional designer.
As the result of case application in this research, it was confirmed that a feature of designer's thinking process: multiple and diverse idea deployment in order to derive diverse solutions by obtaining hints from various viewpoints based on active extraction of design elements. Moreover, an engineer’s thinking process has a following feature: idea deployment by logical and top-down thinking using classification and arrangement based on extraction of design elements along the lines of a theme.
Thus, from the comparative analysis of case applications, it is indicated that each feature of thinking process by different users. As the result, the usage of the unrestricted idea generation and precise design thinking is confirmed, and it is suggested that the design method could perform precise design thinking corresponding to diverse users.

Keywords: Multi-space Design Method; Thinking process; Designer and Engineer; Multi-space Design Model; Design Theory and Methodology

1. Introduction

As science and technology have developed during the 20th century, artifacts (objects) have become more functional. To adapt to these advances, design and industrial engineering fields have been segmented and specialized. In addition, the number of elements and conditions that must be considered to solve Industrial Design and Engineering Design issues has become enormous because modern artifacts have become large-scale and more complex, and user's sense of values has diversified. Under these conditions, it is difficult to obtain innovative design solutions while accounting for elements in a complicated circumstance. Thus, new artifact creation methods are needed. In the conventional research, the Multi-space Design Method (M method) is proposed as a design method to address the aforementioned issues. This design method combines idea generation and analysis methods based on the Multi-space Design Model (M model), which is a framework to arrange elements used in design. Additionally, in the conventional M method, individual designers propose an object’s design. In practice, various members, including designers and engineers, are involved in product development, and the circumstances that employ a design method have diversified. Therefore, the design method itself should accommodate its usage environment. When applying a design method, there are many perspectives to consider, such as those of the users, the object to be designed, and the design process. This study focuses on the viewpoint of diverse users. We extracted the requirements to adapt to various, and proposed the M method that satisfies these requirements.

In the M method, the usefulness for precise design thinking and derivation of a new solution was confirmed thorough case application conducted by a proposer who is a professional designer. However the usefulness of this method for different users is not verified. The purpose of this research is to comparatively analyze case applications of M method by two different experienced users, a professional designer and a professional engineer, and it is indicated that each feature of thinking process.

2. Research Method

2.1. M model

The M model is a design theory that can comprehensively acknowledge all kinds of design procedure. The M model is shown figure 1. The M model is composed of s thinking space and knowledge space, which enables logical reasoning of design practices through the design process. When designing, elements of the objects are broken down into the thinking space, and from the relation of those elements, a novel design will be extracted.

First, the thinking space comprises 4 spaces: the value space, meaning space, state space, and the attribute space. The value space consists of various values such as social value, cultural value, and personal value. Next, the meaning value consists of elements relating to the objects functionality and image. Thirdly, the state space consists of the state of the object, which can be described by the relation of the object and its circumstance. Finally, the attribute space holds elements that express the objects traits that are not effected by its circumstance.

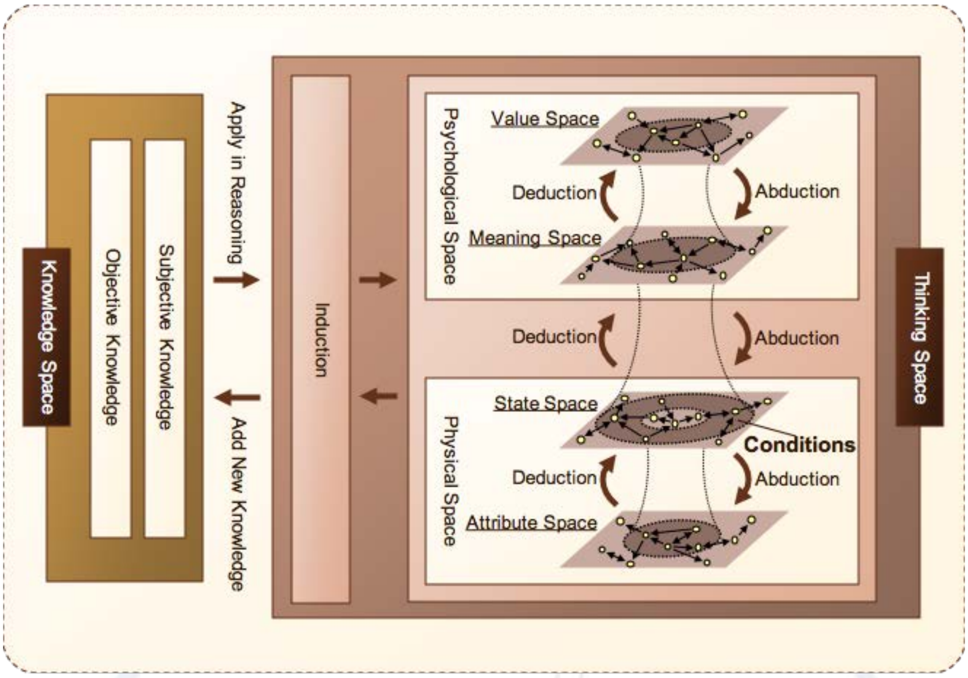


Figure 1 Multi-space Design Model (M model)

The value space and meaning space exist in the psychological space, and the state space and the attribute space exist in the physical space. In addition to the thinking space, the M model is comprised of 2 kinds of knowledge spaces. One is the objective knowledge space, where the knowledge consists of generality to everyone, and the other is the subjective knowledge space, where the knowledge is based on experience and characteristics. In short, the M model is created by 4 spaces in the thinking space and 2 kinds of knowledge in the knowledge space.

2.2. Design process based on M model

The design process based on the M model is shown figure 2. As shown in the figure 1, the design process is mainly divided into 3 processes. The first process is the concept design, where mainly the psychological elements are considered. The second process is the basic design, where the meaning space and physical spaces are mainly considered. The final process is the detail design, where mainly the physical elements are considered and optimized. Furthermore, the concept and basic design both conduct a bottom up process and a top down process through the design process, whereas the detail design only conducts a top down design through the process.

2.3. M method

The M method proposed in previous studies was formed by introducing the viewpoint of the M model into both the design generation–based bottom-up type and the analysis-based top-down type of design deployment. Specifically, existing idea generation and analysis methods were considered as bottom-up and top-down processes, respectively. After classifying the methods, the selection guidelines were identified for each method. A multi-space perspective was then introduced to each classified method to build multi-space idea generation and multi-space analysis methods. Combining these methods into the M method facilitated the arrangement of design elements, allowing novel and highly complete design solutions to be obtained.

2.3.1. Subject of conventional M method

The conventional M method was proposed by focusing on artifact design via an individual designer. In reality, product design involves a team of people, and objects are often designed by expanding from tangible objects to intangible concepts. Consequently, design issues have become more complex, and design methods must be able to adjust to the diversification of

usages including design processes, users, and the object to be designed. To propose a design

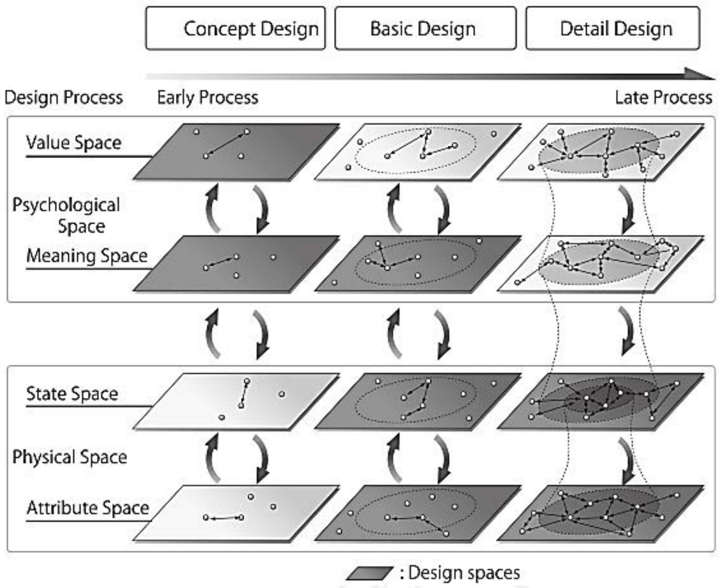


Figure 2 Design process based on M model

method capable of adapting to diverse usages, the framework of the M method must be established by considering the characteristics of diverse users. Additionally, the diversification of usage environments may cause an idea generation method to be used in a top-down and an analysis method to be used in a bottom-up. Thus, a classification from a unified perspective may increase the flexibility of each method.

This method is based on the M model, one of the design theory frameworks. Its main features are the adoption of a perspective based on circumstance and on multi-space. Circumstance refers to the usage environment, including the user and the ways in which artifacts are used. Circumstance has an impact of value, meaning and state.

2.3.2. Classification of idea generation and analysis methods

The purpose of this section is to establish selection guidelines to choose suitable methods for specific design environments and user preferences. Idea generation and analysis methods, which have been traditionally classified according to different perspectives, herein are classified according to a unified perspective.

2.3.3. Classification method

80 idea generation and analysis methods were extracted, which were used to design actual artifacts. These 80 methods were extracted from the following publications and references published within a five years (2001 to 2005): papers published by the Japanese Society for the Science of Design (249 articles), papers published by the Japan Society for Design Engineering (161 articles), papers published by The Japan Society of Mechanical Engineers (289 articles), journal articles published by the Japan Creativity Society (53 articles), Design Encyclopedia, Mechanical Engineers' Handbook (Design Series), and encyclopedias and manuals related to creation techniques.

Then the extracted idea generation and analysis methods were classified based on the M model in which thinking space, design process, and design thinking were used as evaluation

criteria. The three evaluation criteria were further divided. Thinking space was divided into value, meaning, state, and attribute space, while the design process was divided into conceptual, basic, and detailed design. Design thinking was divided into extraction, classification, qualitative structure, and quantitative structure. Table 1 shows all of the evaluation criteria. Here, "extraction" refers to extracting detailed design elements of the object. "Classification" refers to grouping of similar design elements. "Qualitative structure" and "quantitative structure" refer to the structures formed via linking qualitative and quantitative connections between elements in causal and hierarchical relationships, respectively. In this section, cluster analysis using Ward's method was conducted to classify idea generation and analysis methods. Classifications were repeated until the cluster analysis method merged all the clusters.

Table 1 Evaluation criteria

	Item	Evaluation
Thinking Space	Value Space	The design is performed in value space
	Meaning Space	The design is performed in meaning space
	State Space	The design is performed in state space
	Attribute Space	The design is performed in attribute space
Design Process	Concept Design	Is it used at a conceptual design ?
	Basic Design	Is it used at a basic design ?
	Detail Design	Is it used at a detail design ?
Design Thinking	Exstraction	Is it extracting ?
	Cllasification	Is it classifying ?
	Qualitative Structure	Is it structuring qualitatively ?
	Quantitative Structure	Is it structuring quantatively ?

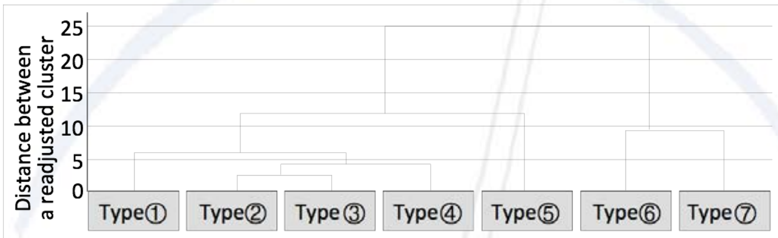
2.3.4. Classification results

The 80 idea generation and analysis methods were evaluated based on the aforementioned evaluation criteria, and cluster analysis was conducted based on the evaluation results. Figure 3 shows the results of the cluster analysis; the 80 methods were classified into seven distinct types.

2.3.5. Characteristics of each Cluster

Based on figure 3 and the evaluation results, the characteristics of the seven types were analyzed. Table 2 shows the characteristics and selection guidelines. By classifying the seven types of idea generation and analysis methods as guidelines, suitable methods could be applied to solve design issues. Furthermore, various combinations of idea generation and analysis methods were possible because the combinations were classified using a unified perspective. Therefore, the applied methods could be tailored to different design issues involving various users, design processes, and objects to be designed.

Table 2 Characteristics and selection guidelines



Design process	Concept design		Basic design	Detail design
Thinking space	Value ·Meaning	Value ·Meaning ·State ·Attribute	Meaning ·State ·Attribute	State ·Attribute
Design thinking: Extraction	Type ① The method of extracting elements by focusing on value and meaning space. Catalog Method, NID Method, Alphabet System, Casting Method	Type ② The method of extracting elements by focusing on value, meaning, state, and attribute space. Mood Board, Checklist Method, Pair Association Analysis, Hope Points Listing Method, Weak Points Listing Method, Gordon Method, Incentive Word Method, Focal Spot Method, △ ○ □ Idea Generation Method, Bionics Method, Brain Storming, Card BS, Brain Writing, Card BW, Synectics, Reverse Setting Method, Virtual Matter Method		
Design thinking: Classification		Type ③ The method of classifying elements by focusing on value, meaning, state, and attribute space. Positioning Method, Cross method, Card method, KJ method, Morphological Analysis, Attributions Listing Method, Affinity Diagram Method, QFD		
Design thinking: Qualitative structure		Type ④ The method of performing qualitative structuring of elements by focusing on value, meaning, state, and attribute space Mind Map, Stop and Go BS, NM Method, Characteristic Diagram, Story Method, Relevance Tree Method, Routes Chart Method, ZK Method, Laddering, Association Diagram Method, Protocol Analysis	Type ⑤ The method of performing qualitative structuring by focusing on meaning, state, and attribute space. Input and Output Method, Work Design Method, Business Design Method, Matrix Method, T.T HS Method, Triz Method, Causality Analysis Method, FEMA, FTA, Petri Net, ISM, Rough Sets, Decision Tree	
Design thinking: Quantitative structure			Type ⑥ The method of performing quantitative structuring by focusing on meaning, state, and attribute space. DEMATEL, Correspondence Analysis, Self-Organizing Map, Quantification Theory Type Ⅲ, Quantification Theory Type Ⅳ, Dual Scaling, Factor Analysis, Cluster Analysis, Identify Mapping Model, Principal Component Analysis, Multi-Dimensional Scaling, Covariance Structure Analysis, Quantification Theory Type Ⅰ, Quantification Theory Type Ⅱ, Fuzzy Inference, Cohort Analysis, Canonical Correlation Analysis, Path Analysis	Type ⑦ The method of performing quantitative structuring by focusing on state and attribute space. Heuristic Idea Generation Method, Response Surface Method, Hierarchical Neural Network, Multiple Regression Analysis, Ordinary Differential Equation, Interconnected Neural Network, Algebra education, Discriminant Analysis, Partial Differential equation

Figure 3 Result of Cluster analysis

3. Proposal of a Multi-space Design Method (M method) corresponding to various usage

3.1 Outline of the M method corresponding to various usage

This section outlines our highly adaptive M method based on the aforementioned framework and selection guidelines for idea generation and analysis methods. The design method consisted of idea generation and analysis methods, which were incorporated from the viewpoint of the M model. As described in chapter 2, the selection guidelines, which were based on a unified perspective, allowed the appropriate method to be selected for the design issue as well as to meet the needs of the designers and engineers. These Multi-space methods allow users who are unfamiliar with the M model to design objects based on a Multi-space perspective.

3.2 Design deployment using the M method

Design deployment using our proposed design method shows following case application. First, the selection guidelines are used to determine the idea generation and analysis methods appropriate for the design issue. Then the viewpoint of the M model is applied to the selected methods, and elements including sketches and pictures are extracted. Thus the design deployment is performed.

4. Case application

In this section, the case studies applying our proposed M method is described. The purpose is to be indicated that each feature of thinking process by different design users. We conduct two types of case studies in which the design users are a professional designer and a professional engineer.

4.1. Outline of case application

The selected object to be designed was a bench because it can be designed from both a mechanical and an artistic perspective. Additionally, the design elements of benches were not too complicated. Thus, both designers and engineers should be able to design one. Because the differences between design implementers should become most apparent in early processes, we decided to perform a conceptual design. The case study participants were asked to design a bench to be placed in a park with a beautiful sunset. The participants initially selected methods suitable to the design issue according to the classification table in the preceding chapter. The viewpoint of the M model is then introduced to the selected methods, and the participants performed conceptual design using these methods. Conducting case studies using two types of design participants verified the usefulness of our method for users in different fields.

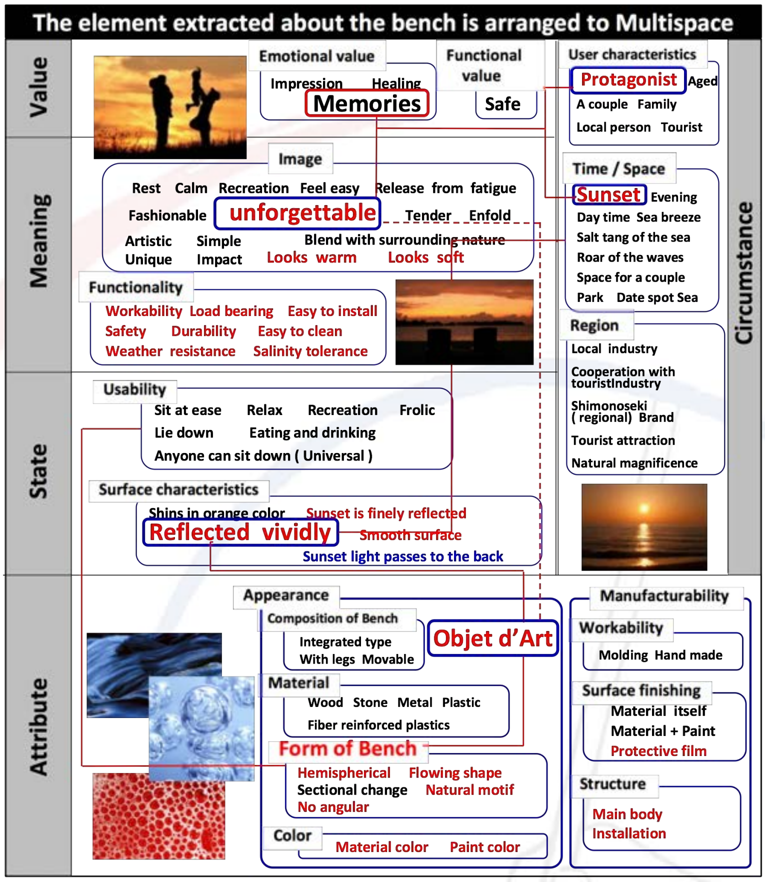


Figure 4 Element relation diagram by a designer

Figure 5 Sketch by a designer

4.2. Design by a single designer or engineer

4.2.1 Design by a single designer

The designer in this case study was a male in his 50s. Table 3 shows the methods he selected. With regard to thinking space, the designer considered meaning space in every method. He seemed to focus on image and function as he designed the bench. With regards to design thinking, he focused on element extraction. In particular, after extracting and classifying the elements to some degree in the checklist method, the selected method confirmed whether elements were missed. The designer obtained hints from various viewpoints to test many ideas. In the end, the designer created an element relationship diagram (figure 4) and sketches for idea deployment (figure 5). In order to make the bench memorable, artwork was tied into an unforgettable image, and the concept entitled, "Sunset Theater, Sunset and the Protagonist, and the Objet d'Art" was conceived.

Table 3 Selected method by a designer

Selected Method	Thinking Space	Design Thinking
Casting Method	Value, Meaning	Extraction
Mood Board	Value, Meaning	Extraction
Virtual Matter Method	Meaning, State	Extraction
Card Method	Meaning, State, Attribute	Classification
KJ Method	Meaning, State, Attribute	Classification
Checklist Method	Meaning, Attribute	Extraction
Association Diagram Method	Value, Meaning, State, Attribute	Qualitative Structure

4.2.2. Design by a single engineer

The engineer in this case study was a male in his 60s. Table 4 shows the methods he selected. With regard to the thinking space, the selected methods considered psychological spaces, such as value space and meaning space, as well as physical spaces, such as state space and attribute space. With regard to design thinking, the engineer extracted, classified, and then arranged elements from a theme. He seldom changed his way of thinking, and proceeded in a logical, top-down manner. The engineer created an element relationship diagram (figure 6). Upon speculating the market needs and arranging the requirements related to the concept, he came up with the concept entitled, "ZIGZAG BENCH SEAT facing the sunset." Figure 7 is a sketch of his idea.

Table 4 Selected method by an engineer

Selected Method	Thinking Space	Design Thinking
Mood Board	Value, Meaning, State, Attribute	Extraction
KJ Method	Value, Meaning, State, Attribute	Extraction, Classification

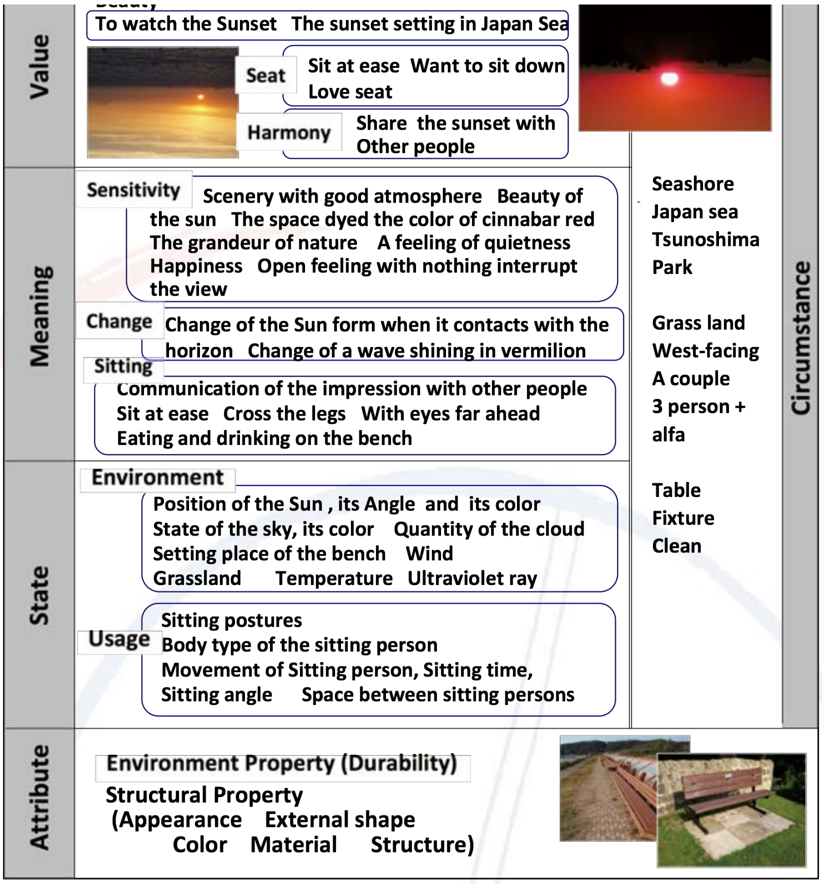


Figure 6 Element relation diagram by an engineer

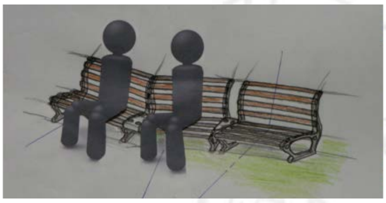


Figure 7 Sketch by an engineer

5. Discussion of the comparison between designer and engineer designs.

First, table 3 and 4 clearly demonstrate a difference in the types and numbers of design methods selected by the designer and engineer. Therefore, our proposed M method allows users to select methods to meet their individual characteristics and style of design deployment.

Next, figures 4 and 6 indicate that the designer and engineer extracted similar numbers of elements. The elements were related to various images and functions, such as "beauty of the sunset" and "emotional scenery." We expect that pictorial information aided in handling meaning elements. The designer examined form via pictures in attribute space, suggesting that pictorial information can help consider various elements of space.

Thirdly, although designers typically do not handle state elements in state space, the designer in our case study was able to sufficiently extract elements that are hard to quantify, such as "the light shines through to the back" and "shines in orange," indicating that our method facilitated the treatment of the state space for designers. The engineer extracted quantifiable elements, such as "the position of the sun," suggesting that the characteristics determined in Chapter 2 were exhibited.

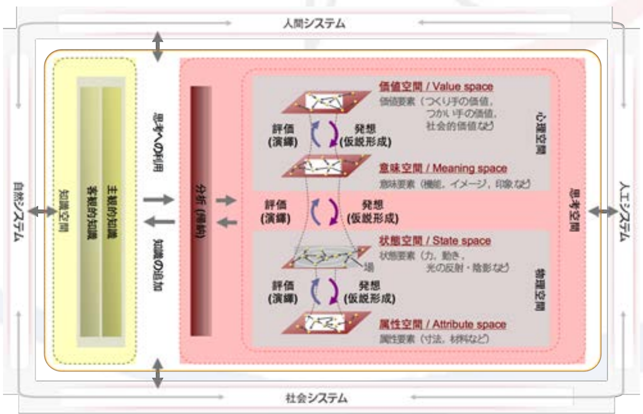
Fourthly, our proposed M method also redefined circumstance, which allowed many correlations to be made between the elements of circumstance and psychological elements in value space and meaning space. Our method led to both the designer and engineer generating element of circumstance, such as "protagonist" and "west-facing". Then both tangible objects and intangible concepts could be incorporated in the design.

Finally, through case applications in this research, it was confirmed that a feature of designer's thinking process: multiple and diverse idea deployment in order to derive diverse solutions by obtaining hints from various viewpoints based on active extraction of design elements. Moreover, an engineer's thinking process has a following feature: idea deployment by logical and top-down thinking using classification and arrangement based on extraction of design elements along the lines of a theme

6. Conclusions

In this research, it was confirmed that a feature of different user's thinking process through the case application applying the M method. Specifically, we constructed usage guidelines to practically employ various idea generation and analysis methods by reclassifying the methods according to a unified perspective. Additionally, it was indicated that each feature of the thinking process by both a designer and an engineer from the comparative analysis of case application of M method. Moreover, through case applications applying the M method, the usefulness was indicated precise design thinking by different users.

In a future study, the usage from single to collaboration should be considered. Furthermore, the usefulness of our method should be verified for different design processes by applying it to late processes such as detailed design.



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