CLASSIFICATION OF IDEA GENERATION METHODS FOR DESIGN BASED ON MULTISPACE DESIGN MODEL

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Abstract: This study strives to provide practical assistance to designers and engineers in selecting the most appropriate idea generation method currently utilized in the field of design. Based on the Multispace Design Model, the features from five viewpoints (design thinking, design knowledge, design object, design process, and design method) were used to classify 36 idea generation methods, which resulted in five distinct clusters. Additionally, by considering the relationships between the combinations of these five viewpoints and the clusters, we clarified each idea generation method with regard to practical design situations.

Keywords: Classification, Idea Generation Method, Multispace Design Model

1. Introduction

In 1962, J. C. Jones and his peers held The Conference on Design Methods [1] in London; this is one of the earliest examples of research on design methodology that systematically considers diverse design methods. Since then many studies have been conducted. Some prominent examples include the study of design methodology from an engineering approach by G. Pahl and W. Beitz [2], the work of V. Hubka and W. E. Eder on design methodology based on design process modeling in the field of engineering design [3], and the proposals of C. Alexander on design problems and solutions using patterns in the field of industrial design [4]. Additionally, N. Cross has offered a comprehensive evaluation of the research in design methodology, and has characterized the relationship between design and the science applied to design methodology based on the three approaches: Scientific Design, Design Science and the Science of Design [5]. His work presents a useful overview on the research into design methodology.

The practical field of design has recently seen the widespread application of idea generation methods to generate diverse and creative design proposals. However, idea generation methods are not limited to the design field; they are recognized as useful methods for providing support to creative processes in various disciplines, including business and academic fields. To date, many methods have been proposed [6, 7]. For example, one well known method is the Brain Storming method [8], which is an idea generation method to facilitate the generation of diverse design ideas through free discussion without concurrent evaluation of the generated ideas. Despite the vast number of methods, little research systematically examining the various idea generation methods currently available has been conducted from the perspective of design methodology. Consequently, designers and engineers tend to select and utilize idea generation methods based on individually accumulated knowledge and experience. Hence, a set of guidelines, which provides selection and application rules for idea generation methods based on their appropriateness in terms of the design situation and factors such as differences in design object and design processes, would be a useful practical tool.

In consideration of the context outlined above, this study was carried out to provide practical assistance to designers and engineers for selecting the most appropriate...
idea generation method currently utilized in the field of design. Based on the Multispace Design Model [9] which can describe the generality of designing, the study aims to clarify the relative usefulness of idea generation methods with respect to diverse design situations. The Multispace Design Model is used because studies on the correspondence to design situation which utilized the models, such as a design method in consideration of the relationship between design object and circumstance [10], a design method in consideration of the difference of the design process [11], and the difference of research method in industrial design and engineering design [12]. In this study, we initially identified the idea generation methods to be examined. Then we assigned a binary value for each item variable extracted from the Multispace Design Model, and conducted cluster analysis on the selected idea generation methods. Finally, the features of idea generation methods included in each cluster established by the cluster analysis were examined according to multiple viewpoints based on the Multiple Design Model.

Although there are many idea generation methods, this study considers only those that meet the following three criteria: (i) the method must be used in artifact design, (ii) it must be widely recognized in the field of design research as well as in practical design situations, and (iii) it must have general processes for its idea generating techniques. For these reasons, business-related idea generation methods, such as those used to formulate corporate management strategies and personnel management as well as individual methods (individual styles) without general idea generation are not considered.

2. Multispace Design Model

2.1 Outline of Multispace Design Model

The Multispace Design Model is a model for the framework of design theory. It can describe the generality of diverse design, e.g., industrial design, engineering design, etc. [9]. This model is based on General Design Theory, which effectively explains design activities [13]. As shown in Figure 1, the model consists of three concepts: space describing elements of design objects and reasoning with respect to their relationship, space describing knowledge leading to reasoning, and the system surrounding the object. These concepts are defined as Thinking Space, Knowledge Space, and External System, respectively.

2.2 Thinking Space

Thinking Space can be divided into four spaces: Value Space, Meaning Space, State Space, and Attribute Space. The first two spaces comprise Psychological Space, while latter two comprise Physical Space. Moreover, Value,
Meaning, and State Spaces describe elements, which compose human, object, acts, and the environment as well as their relationships. Attribute Space describes elements making up the composition of the object and their relationships. These elements and relations are selected and controlled by knowledge. In Value Space, elements showing value, including cultural value and functional value, and the relationship between these elements are described, whereas in Meaning Space, elements showing function, image, etc., and their relationships are described. State Space describes elements exhibiting physical quantities generated under certain conditions, stress of an object caused by an external force, elements displaying a condition, an object, and their relationships. The condition is various physical elements in the circumstance of artifacts such as environmental elements, human elements and other artifact's elements. In Attribute Space, elements exhibiting geometrical and physical properties, including dimensions and materials in technical drawings, and their relationships are described.

In spaces, three thinking processes are described: analysis of design problems, idea generation of design candidates, and evaluation of design candidates. These processes are defined as "analysis", "idea generation", and "evaluation", respectively. Furthermore, "analysis" can be further divided into three processes: "extraction of elements", "clarification of relationship between elements", and "explanation of the model". In Thinking Space, reasoning is described based on the knowledge. Instead of knowledge, a model is utilized for reasoning, and the process of constructing this model is defined as "modeling".

2.3 Knowledge Space

Knowledge Space consists of two types of knowledge: Objective Knowledge and Subjective Knowledge. Objective Knowledge describes general knowledge, for example theories, methods, facts, and results based on natural science, including laws of physics, social science, and humanities. In contrast, Subjective Knowledge describes peculiar knowledge such as personal or group rules based on experience and ideologies. Subjective Knowledge can be divided into two type of knowledge, depending on different views: Explicit Knowledge and Tacit Knowledge. Explicit Knowledge is knowledge that can be described in certain media; that is, it can be transmitted to another person. On the other hand, Tacit Knowledge is knowledge that is difficult to transfer to another person by means of communicating, e.g., intuitions and sensibilities [14].

3. Properties of idea generation methods

This study used the following process to identify and select idea generation methods that are applied to practical design situations. First, we extracted all idea generation methods referenced in academic journals on design during a five-year period (all journals published between 2001 and 2005, 699 papers in total). Additionally, we extracted the methods referenced in dictionaries and handbooks edited by the academic societies responsible for publishing those journals. Specifically, these idea generation methods were extracted from papers published by the Japanese Society for the Science of Design (249 papers), the Japan Society of Design Engineering (161 papers), the Japan Society of Mechanical Engineers (289 papers), as well as the dictionary published by the Japanese Society for the Science of Design [15] and the Mechanical Engineer's Handbook published by the Japan Society of Mechanical Engineers [16]. Of the papers published by the Japan Society of Mechanical Engineers, those falling into Series C, which includes the field of design, were considered. Then these papers were further narrowed by selecting those containing the term "design" for further examination. Next, references to idea generation methods were extracted from research papers published by the Japan Creativity Society during a five-year period (all journals published between 2001 and 2005, 53 papers in total), as well as dictionaries [17] and handbooks [6, 7, 18, 19] on creative techniques. Moreover, the heuristic method was added as a current idea generation method because design support systems based on global research with a computer have been recognized [20, 21]. Finally, interviews were conducted with experts on design methodology and practicing designers in which the practical applicability of the extracted idea generation methods to artifact design were discussed. This process allowed the number of idea generation methods to be narrowed down to 36 methods.

Table 1 shows the 36 idea generation methods selected as samples for classification by aforementioned process. For instance, the Brainstorming method (Table 1, entry 1) is a method to generate numerous ideas for various design themes through free discussion mediated by a chairperson without criticism or evaluation. In contrast, Attritions listing method (entry 10) is a method to generate ideas for technical problems of a product. New ideas are generated by analyzing and focusing the attribute of design. The thinking process of idea generation consists of "analysis", "idea generation", and "evaluation" based on Thinking Space in the Multispace Design Model. Additionally, "objective knowledge" in idea generation consists of
Table 1. Idea generation methods

<table>
<thead>
<tr>
<th>No.</th>
<th>Method name</th>
<th>No.</th>
<th>Method name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brain Storming</td>
<td>19</td>
<td>Alphabet System</td>
</tr>
<tr>
<td>2</td>
<td>Card Brain Storming</td>
<td>20</td>
<td>Idea Generation Method</td>
</tr>
<tr>
<td>3</td>
<td>Brain Writing</td>
<td>21</td>
<td>Positioning Method</td>
</tr>
<tr>
<td>4</td>
<td>Card Brain Writing</td>
<td>22</td>
<td>Gordon Method</td>
</tr>
<tr>
<td>5</td>
<td>Casting Method</td>
<td>23</td>
<td>Synectics</td>
</tr>
<tr>
<td>6</td>
<td>Mind Map</td>
<td>24</td>
<td>NM Method</td>
</tr>
<tr>
<td>7</td>
<td>Morphological Analysis</td>
<td>25</td>
<td>Bionics Method</td>
</tr>
<tr>
<td>8</td>
<td>Checklist Method</td>
<td>26</td>
<td>KJ Method</td>
</tr>
<tr>
<td>9</td>
<td>Matrix Method</td>
<td>27</td>
<td>Card Method</td>
</tr>
<tr>
<td>10</td>
<td>Attractions Listing Method</td>
<td>28</td>
<td>Cross Method</td>
</tr>
<tr>
<td>11</td>
<td>Hope Points Listing Method</td>
<td>29</td>
<td>Business Design Method</td>
</tr>
<tr>
<td>12</td>
<td>Weak Points Listing Method</td>
<td>30</td>
<td>ZK Method</td>
</tr>
<tr>
<td>13</td>
<td>TRIZ</td>
<td>31</td>
<td>Input and Output Method</td>
</tr>
<tr>
<td>14</td>
<td>Mood Board</td>
<td>32</td>
<td>Work Design Method</td>
</tr>
<tr>
<td>15</td>
<td>Focal Spot Method</td>
<td>33</td>
<td>Stop and Go Brain Storming</td>
</tr>
<tr>
<td>16</td>
<td>Pair Association Analysis</td>
<td>34</td>
<td>NID Method</td>
</tr>
<tr>
<td>17</td>
<td>Catalog Method</td>
<td>35</td>
<td>T.T.HS Method</td>
</tr>
<tr>
<td>18</td>
<td>Incentive Word Method</td>
<td>36</td>
<td>Heuristic Idea Generation Method</td>
</tr>
</tbody>
</table>

“explicit knowledge” and “tacit knowledge”, while “subjective knowledge” consists of “explicit knowledge” based on Knowledge Space in the Multispace Design Model. Explicit knowledge includes elements described by words or sentences because concepts can be explicitly described by signs or text. In contrast, tacit knowledge includes elements that are described by pictures or sketches because these concepts cannot be described by signs or text. Therefore “analysis”, “idea generation”, “evaluation”, “explicit knowledge”, “tacit knowledge”, “objective knowledge”, and “subjective knowledge” are defined as properties of the idea generation methods based on Thinking Space and Knowledge Space in the Multispace Design Model. Moreover, analysis can be subdivided.

Table 2 shows the data collected from the respective properties of each method, which is used as the basis of cluster analyses in this study. The first entry in Table 1 can illustrate the data collection process using the Brain Storming method (BS method) as an example. The first item considered is “Analysis”, which is part of the “Design Thinking” viewpoint. The BS method does not reference physical elements such as numerical values or formulas, but instead is concerned with psychological elements as expressed through keywords. These keywords are not limited in any way, and there is not a distinction between value and meaning. Hence, “Value and Meaning Space” is circled. Next, “Idea Generation” and “Evaluation” are considered. Only “Idea Generation” is circled because the BS method does not involve analysis, but is a method intended to generate as many design factors as possible. The next viewpoint considered is “Design Knowledge”, which is initially divided into two items, “Objective Knowledge” and “Subjective Knowledge”. Because the BS method does not consider design elements containing tacit knowledge; only “Objective Knowledge” and the “Explicit Knowledge” sub-item of “Subjective Knowledge” are circled. This process was used to assess the properties of all the idea generation methods. Then a binary value was assigned to

Table 2. Properties of idea generation method

<table>
<thead>
<tr>
<th>View point</th>
<th>Item</th>
<th>Property of an idea generation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design thinking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>analysis</td>
<td>Psychological Space</td>
<td>Analyzing elements in both Value and Meaning Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyzing elements divided into Value and Meaning Space</td>
</tr>
<tr>
<td></td>
<td>Physical Space</td>
<td>Analyzing elements in both State and Attribute Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyzing some elements divided into Value and Attribute Space</td>
</tr>
<tr>
<td></td>
<td>Psychological and Physical Space</td>
<td>Analyzing relations with elements between Psychological and Physical Space</td>
</tr>
<tr>
<td>idea generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generating new elements based on analysis</td>
</tr>
<tr>
<td>evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaluating elements based on analysis</td>
</tr>
<tr>
<td>Objective Knowledge</td>
<td>explicit knowledge</td>
<td>Using explicit knowledge in general knowledge</td>
</tr>
<tr>
<td>Subjective Knowledge</td>
<td>tacit knowledge</td>
<td>Using tacit knowledge in group or personal knowledge</td>
</tr>
<tr>
<td></td>
<td>explicit knowledge</td>
<td>Using explicit knowledge in group or personal knowledge</td>
</tr>
</tbody>
</table>
each variable: 1 for circled data and 0 for blank data. Clustering was then carried out using the data from the 36 idea generation methods.

4. Cluster analysis

To clarify the idea generation methods, they were analyzed using Cluster Analysis, which is a statistical method that defines the similarity of select objects from the distance between them and classifies these objects into different groups. Cluster analysis consists of a hierarchical method and a partitioning-optimization method. To obtain a hierarchical structure and to avoid the chain effect, the present study employs Ward’s method that is one of the hierarchical methods. Ward’s method makes a cluster using non-similar level data according to the criterion where the sum of the square of a cluster is minimized in a new cluster. In this method, Euclidean distance \( d_{ij} \) is used as the non-similar level data by equation (1). For qualitative data, the Euclidean distance is calculated as binary data.

\[
d_{ij} = \left( \sum_{i=1}^{m} (x_{ai} - x_{bj})^2 \right)^{1/2}
\]

Concretely, the distance is described such that the variable number is \( p_i \) where the variable is \( x_{1i}, x_{2i}, \ldots, x_{pi} \) \((i=1,2, \ldots, n)\) and the subject number is \( m \). Hence, the cluster is \( I, M \), and the combined cluster is \( IM \), which are described by the variable number \( k \) where the variable is \( x_{ik}, x_{mk}, x_{nk} \) and the subject number is \( n_1, n_m \). According to the above case, equation (1) gives equations (2)-(5). In equation (5), the cluster and subject are combined to minimize the value of \( \Delta S_{IM} \). In this manner, this process repeats until all the clusters are combined.

\[
S_I = \sum_{i=1}^{n_1} \sum_{k=1}^{m} (x_{ik} - \bar{x}_{i-k})^2
\]

\[
S_M = \sum_{i=1}^{n_2} \sum_{k=1}^{m} (x_{mk} - \bar{x}_{m-k})^2
\]

\[
S_{IM} = \sum_{i=1}^{n_1} \sum_{k=1}^{m} (x_{n_{1k}} - \bar{x}_{n_{1-k}})^2
\]

\[
\Delta S_{IM} = S_{IM} - S_I - S_M
\]

Figure 2 shows the cluster process (Dendrogram). In the present study, for the condition where two or more methods are included in one cluster, the number of clusters was set to 5. Furthermore, Table 3 shows the relationships between the properties (“type of thinking space”, “with or without evaluation”, and “type of knowledge”) and clusters. The following chapter describes the results after considering the features of these clusters from the viewpoints of design thinking, design knowledge, design object, design process, and design methodology based on the Multispace Design Model.

5. Idea generation methods for design and their classification

This chapter outlines the differences in design thinking, knowledge used in design thinking, and design objects in both the design process and design method based on the Multispace Design Model. This examination was carried out in reference to the results of the cluster analysis outlined in the previous chapter. Various features of the idea generation methods considered in this study were then clarified according to an integrated approach of these viewpoints.

5.1 Idea generation methods in design thinking

Table 3 shows that the idea generation methods included in clusters 1 and 2 are mainly used for idea generation without evaluating Psychological Space. The results indicate that these methods can assist in idea generation of a concept regarding function or style in the early process of design. Idea generation methods in cluster 3 can generate new ideas based on the analysis of Psychological Space with evaluation. Moreover, idea generation methods in cluster 4 can generate new ideas based on the analysis of Physical Space with evaluation. Hence, methods in clusters 3 and 4 can help designers and engineers generate realistic design solutions with respect to physical elements.

A practical example would be the design of a household electrical appliance. To design a conceptual model that would be manufactured in 3-5 years with unclear development limitations and undefined evaluation criteria for design problems, the most appropriate methods would likely be those found in cluster 1, such as Mind Maps because cluster 1 methods can be used to support the generation of new design concepts that are not limited by preconceived notions. By contrast, methods in cluster 2, such as the BS method, would be most appropriate to design a new model that would be manufactured in 1-2 years with explicit development limitations and design problems because cluster 2 methods can be used to support the generation of overall functionality and structure. Furthermore, methods in cluster 3, such as the NM method, would be most appropriate to make minor changes to an existing model that would be manufactured within a year and has established limitations on functionality and structure because these methods can be used to support the generation of novel proposals for partial alterations to pre-existing conditions.
Figure 2. Result of cluster analysis

Table 3. Relationships between properties and clusters

<table>
<thead>
<tr>
<th>Design thinking</th>
<th>Using tacit knowledge and explicit knowledge</th>
<th>Using explicit knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>in Psychological Space</td>
<td>not evaluating elements</td>
<td>Cluster 1</td>
</tr>
<tr>
<td>evaluating elements</td>
<td></td>
<td>Cluster 3</td>
</tr>
<tr>
<td>in Psychological and Physical Space</td>
<td>evaluating elements</td>
<td>Cluster 4</td>
</tr>
<tr>
<td>in Physical Space</td>
<td>evaluating elements</td>
<td>Cluster 5</td>
</tr>
</tbody>
</table>
5.2 Idea generation methods in design knowledge

Table 3 shows that the idea generation methods in cluster 1 assist in generating new ideas using tacit knowledge. Therefore, these methods can help designers and engineers generate design solutions intuitively, whereas idea generation methods in clusters 2, 3, 4 and 5 aid in generating new ideas using only explicit knowledge. Therefore, these methods can assist designers and engineers in deriving design solutions logically.

A practical example would be the color design of a household electrical appliance. Methods in cluster 1, such as the Mood Board method, can support the generation of new concepts based on images such as photographs and sketches (tacit knowledge). Therefore, they seem optimal for the design of new color concepts. By contrast, the design of color variations for mobile handsets and computers would be optimally supported by methods in cluster 3, such as the KJ method, as they can support the generation of ideas capable of consolidating the relationships between diverse user demands.

5.3 Idea generation methods in design object

Using the Multispace Design Model as a framework of design theory, the object of design can be divided into two concepts [9]: External-focus Design in the External System and Internal-focus Design in the Internal System. The External System is defined as a system composed of elements and their relationships in the conditions of the design object. The Internal System is defined as a system composed of elements and relationships between them within the design object. The main object of External-focus Design is an External System, while that of Internal-focus Design is an Internal System. In industrial design, designers create new forms and structures of artifacts based on cultural and spiritual values. Designers give attention to the relationships between the design objects and external system, which include user and usage circumstance. Therefore, industrial design is expressed as External-focus design. In engineering design, engineers create new form and structure of artifacts based on science. Engineers give attention to the internal system, which include the form and structure to realize functions and improve performances. Thus, engineering design is expressed as Internal-focus design. Based on the Multispace Design Model, the External-focus Design is described by Value Space, Meaning Space, and State Space, while the Internal-focus Design is described by State Space and Attribute Space.

Table 3 shows that the idea generation methods in clusters 1, 2, and 3 are mainly used to generate new ideas in Psychological Space, whereas those in cluster 4 are used in both Psychological and Physical Space. Because Physical Space is an External System as a condition of design object, these methods can assist in generating solutions for External-focus Design. In contrast, methods in cluster 5 should help generating new ideas based on analysis in only Physical Space; thus, these methods should assist in generating solutions for Internal-focus Design. Figure 3 shows the position of each cluster in the design object.

A practical example would be the design of an interface for a household electrical appliance. The design of the interface buttons and the display panel layout is an example of External-focus design, which must consider the relationship between the interface as a design object and the user and usage environment as circumstance. For this reason, methods in cluster 4, such as the Attributions Listing Method, would be most useful in supporting the generation of layout proposals based on a detailed awareness of the properties for both object and circumstance. By contrast, the design of a detailed form for the buttons and display panel is an example of Internal-focus design, which must principally consider the interface buttons and display panel themselves. Hence, methods in cluster 5, such as the Heuristic method, would be most useful in supporting the formulation of detailed ideas on form through the generation of diverse design proposals.

5.4 Idea generation methods in design process

Based on the Multispace Design Model, the design process can be divided into three steps [9]: conceptual design, basic design, and detail design. In conceptual design, elements and their relationships in Psychological Space are
examined. In basic design, elements in both Psychological and Physical Spaces are examined. In detail design, the relationships between elements in Physical space are examined. Conceptual design can be described by Value Space and Meaning Space, whereas basic design can be described in Value Space, Meaning Space, and State Space, and detail design can be described in State Space and Attribute Space.

Idea generation methods in clusters 1, 2, and 3 generate new idea based on analysis in Psychological Space, and are applicable to conceptual design. Because methods in cluster 4 derive new ideas based on analysis in Psychological Space and Physical Space, these methods can generate solutions to basic design. Furthermore, methods in cluster 5 generate new idea based on analysis in Physical Space, and should be applicable to generate design solutions in detail design. Figure 4 shows the position of each cluster in the design process.

A practical example would be the exterior design of a household electrical appliance. To design exterior images within a conceptual design, methods from cluster 1, such as Mind Maps, and methods from cluster 2, such as the BS method, can support the global examination of ideas generated from diverse images. For exterior structure design within a basic design, methods from cluster 4, such as the Matrix method, can be used to support to generation of ideas based on specific and targeted proposals as these methods can narrow down the exterior structure from multiple design images. Methods from cluster 5, such as the Heuristic method, are optimal for supporting exterior shape design within a detailed design by aiding in the formation of exterior structure ideas through the generation of diverse proposals for shape.

5.5 Idea generation methods in design method

Based on the Multispace Design Model, the design method can be divided into two [9]: emergent design and optimum design. Emergent design includes both bottom-up and top-down processes, whereas optimum design mainly includes top-down processes. In bottom-up processes, diverse design candidates are generated, whereas in top-down processes, diverse design candidates are optimized. Hence, emergent design is applicable to global search problems and different topology problems in the early process of design. However, the optimum design is applicable to local search problems and same topology problems in the late process of design. Concretely, in bottom-up of emergent design, new ideas are generated from relationships between the elements of design objects based on intuition and inspiration of designers and engineers. In top-down of emergent design, new design

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**Figure 4. Position of idea generation methods in design process**

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![Diagram showing the position of idea generation methods in design process](image-url)
ideas in bottom-up process are optimized. Clear design targets, objective functions and conditions, which are needed for optimum process, are set up based on design idea in bottom-up process. In general, new and optimum design solution needs the interaction between bottom-up and top-down process. On the other hand, in optimum design, the analysis of design problems leads to optimum design variable and design solution. The whole elements decide the part elements in this design process. In other words, optimum design is based on top-down process. Hence, emergent design can be described in Physiological Space and Physical Space, while optimum design can be described in Physical Space.

Table 3 shows that the idea generation methods in clusters 1, 2, and 3 are mainly used in Psychological Space, but those in cluster 4 are used in both Psychological and Physical Space. The methods in cluster 5 are mainly used in Physical Space. From these results, the idea generation methods in clusters 1, 2, 3, and 4 are applicable to emergent design, whereas those in cluster 5 are applicable to optimum design.

Table 4. Classification of idea generation methods for design

<table>
<thead>
<tr>
<th>Design object</th>
<th>External-focus design</th>
<th>Internal-focus design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design method</td>
<td>Emergent design</td>
<td>Optimum design</td>
</tr>
<tr>
<td>Design process</td>
<td>Conceptual design</td>
<td>Basic design</td>
</tr>
</tbody>
</table>

- **Cluster 1**
  - Generating new idea based on analysis in psychology space using implicit knowledge and explicit knowledge without evaluation
  - Mind Map
  - Mood Board
  - Catalog Method
  - NID Method

- **Cluster 2**
  - Generating new idea based on analysis in psychology space using explicit knowledge without evaluation
  - Brain Storming
  - Card Brain Storming
  - Brain Writing
  - Card Brain Writing
  - Casting Method
  - Checklist Method
  - Hope Points Listing Method
  - Weak Points Listing Method
  - Focal Point Method
  - Pair Association Analysis
  - Incentive Word Method
  - Alphabet System
  - Idea Generation Method
  - Positioning Method
  - Gordon Method
  - Brainstorming Method

- **Cluster 3**
  - Generating new idea based on analysis and evaluation in psychology space using explicit knowledge
  - Synergics
  - KJ Method
  - Card Method
  - Cross Method
  - Business Design Method
  - 2K Method
  - Input and Output Method
  - Work Design Method
  - Stop and Go Brainstorming

- **Cluster 4**
  - Generating new idea based on analysis and evaluation in psychology and physical space using explicit knowledge
  - Morphological Analysis
  - Matrix Method
  - Attribute Listing Method
  - T.T.i.HS Method

- **Cluster 5**
  - Generating new idea based on analysis and evaluation in physical space using explicit knowledge
  - TRIZ
  - Heuristic Idea Generation Method

A practical example is to design an automotive engine. Methods in clusters 1-4, such as Positioning or Matrix method, can be used in emergent design to generate new concepts, while methods in cluster 5 like the heuristic method can be applied to optimum design to generate detailed shapes.

5.6 Classification of idea generation methods

Table 4 summarizes the results from the examination of the properties of each idea generation method according to the five viewpoints based on the Multispace Design Model. Two types of design thinking, logical thinking and intuitive thinking, form one row, and the two types of design knowledge, explicit knowledge and tactic knowledge, form the other. The columns are comprised of different types of design processes (conceptual design, basic design, detailed design) as well as the main design methods used within those processes (emergent design, optimum design) and the main design object types (external-focus design, internal-focus design). Combining these rows and columns reveals the features of idea generation methods included in each cluster.
Table 4 also shows the classification of idea generation methods in relation to diverse design situations. Because classification is achieved through a combination of design processes, principle design methods and design objects used therein, as well as design thinking and applied design knowledge, this classification should have function as a useful tool for designers and engineers in selecting the appropriate idea generation method for diverse design situations.

6. Conclusions

This study classified various idea generation methods used in the field of design to aid designers and engineers in selecting the appropriate method in diverse design situations. First, variables relating to design thinking and design knowledge were assigned binary values, and then cluster analysis was performed using the sample containing the 36 idea generation methods. These 36 methods were classified into five clusters. Next, based on the Multispace Design Model, five viewpoints (design thinking, design knowledge, design object, design process, and design method) were used to consider the features of the methods within each cluster. The relationship between the combinations of the five viewpoints and the each cluster allowed each idea generation method to be clarified for diverse design situations.

In terms of ongoing research, the results of this study are being applied to design case studies, which will allow us to examine the classification results as well as to evaluate the usefulness of the classification of idea generation methods.

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