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Feature Analysis for the Design of Artifacts with Growing Practical Values and Spiritual Values

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Abstract: Value Growth Design is a design based on a new design paradigm, Timeaxis Design, which incorporates the viewpoint of the time axis into the theory and methodology of design. Value Growth Design enables an object to increase in its practical value, such as its usability, and in its spiritual value, such as affection, the more it is used. This is antithetical to value decay design, seen in artifacts of mass production and mass consumption, which show a decrease in value over time. If such artifacts were able to adapt to the change of environment and the change of value based on the theory of Timeaxis Design, it is expected that their practical values and spiritual values would increase. This can enable artifacts to become appealing to human Kansei and allow users to possess a single artifact over a long range of time with strong affection. However, there are only few studies which have considered the application of Value Growth Design to actual design. Thus, in this research, a case study of existing value growing cases is carried out, followed by a cluster analysis and a discussion of the results which produce nine factors of value growth.

Keywords: Timeaxis Design, Value Growth Design, Multispace Design Model, design science.

1. INTRODUCTION

1.1. Research background

1.1.1. Issues surrounding society

In recent years, as we shift towards a society dependant on mass production and mass consumption caused by the development of industry and the growth of population, environmental

issues due to mass disposal and energy waste have become crucial. In addition, there is a demand for spiritual richness rather than practical richness. Also, since the circumstances of artifacts such as the surrounding environment, and the diverse values of users such as one's preferences may change from to the point of purchase, there is a need to cope with these issues in the field of artifacts design.

1.1.2. Value Growth Design

In order to design artifacts that will meet the needs mentioned above, Value Growth Design, a design methodology which embodies Timeaxis Design, is proposed as an effective solution.

Timeaxis Design incorporates the viewpoint of time into the theory and methodology of design, enabling various conditions and values as well as changes over time to be considered. Other than Value Growth Design, the design of the transition period is also a methodology to embody Timeaxis Design. Value Growth Design allows an artifact to grow in its practical values and spiritual values. The design of the transition period can be applied to large-scale systems with long term transition periods of one state to another. Among such methodologies, Value Growth Design focuses not only on the change over time but also on the spiritual relationship between an artifact and its user, such as the affection and devotion towards an artifact.

When designing artifacts based on the concept of Value Growth Design, it is necessary to focus on the process of usage. This is because practical values and spiritual values of an artifact are expected to be nurtured through various experiences and interactions through the usage after purchase. This process can be clarified by studying the relationship between the user and the physical and mental elements of artifacts which change over time.

On the other hand, to clarify the elements considering the design of artifacts and their relationships mentioned above, a framework is needed for its comprehension. Design science, proposed by Matsuoka, is a framework aimed to elucidate the laws and knowledge concerning design. Furthermore, the Multispace Design Model, proposed based on design science, is a model which organizes the physical and mental elements and its relationships of a certain design object, and also explains the surroundings, the meaning, and value of a design object. The introduction of this model thus becomes valuable in this research.

1.2. Purpose of research

In this research, we clarify the factors of value growth based on the perspective of design science. This makes it possible to express the growth of value, and will become contributory to the application of Value Growth Design.

1.3. Method of research

First, we collected cases of existing value growth designs and organized its elements using the Multispace Design Model. Next, we analyzed the cases by a cluster analysis and applying the perspectives proposed in Value Growth Design. As a result, we were able to extract the factors of value growth.

2. PERSPECTIVES OF ARTIFACTS DESIGN INTRODUCED IN RESEARCH

2.1. Value Growth Design

As shown in figure 1, many existing artifacts have the highest value at the point of purchase and show a decay in value through usage due to the disability to adjust to changing circumstances and

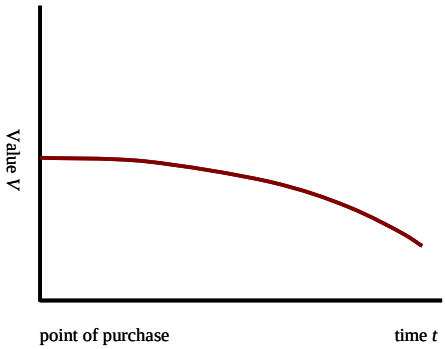

Figure 1: Value decay design

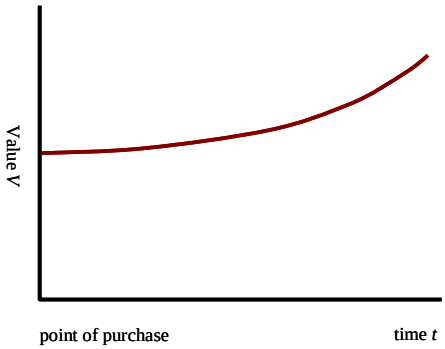

Figure 2: Value Growth Design

users' values. This can be described as a value decay design. An example would be a disposable pen. Opposed to this, Value Growth Design enables an object to adapt to changing circumstances and values, which results in an increased value over time, as shown in figure 2. An example of this would be a fountain pen. By applying Value Growth Design, the design of artifacts which are not only capable of long time usage, but are also focused on spiritual values in addition to practical values will become possible.

2.2. Multispace Design Model

To consider the elements of a design object and their relationships, we introduce the Multispace Design Model, shown in figure 3. The Multispace Design Model consists of knowledge space and thinking space.

Knowledge space consists of two categories: objective knowledge and subjective knowledge. Objective knowledge is comprised of generalities, theories, and methods in natural science, humanities, and social science. In contrast, subjective knowledge depends on personal skills and experiences.

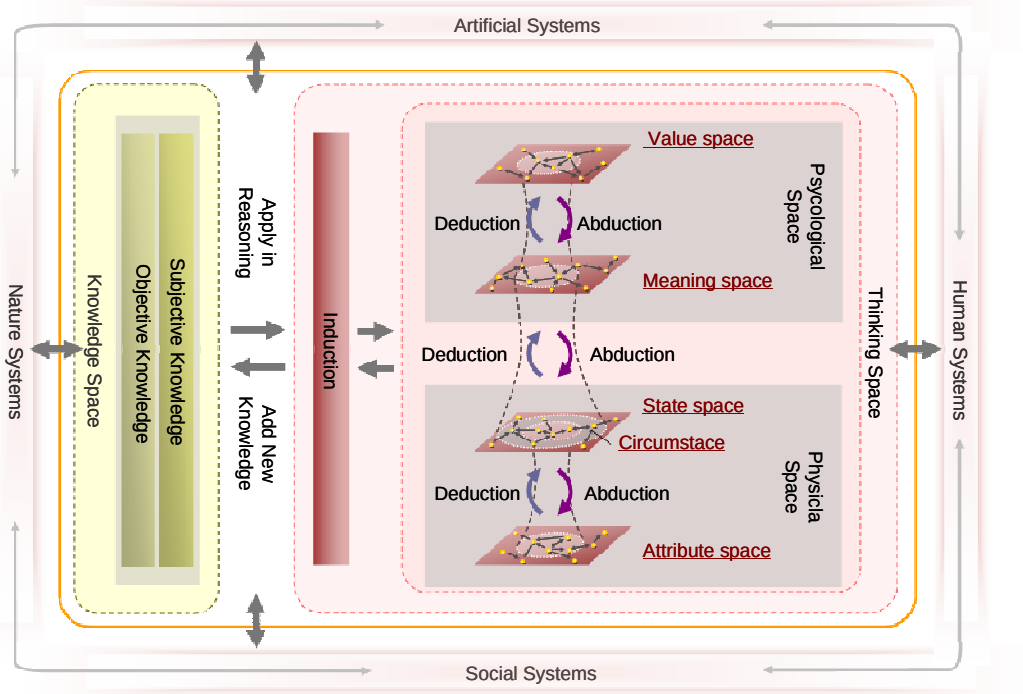

Figure 3: Multispace Design Model

Thinking space can be subdivided into value space, meaning space, state space, attribute space, and circumstance. Value space is a set of elements related to the value that a user gives an artifact (e.g., functional value, cultural value, etc.). The meaning space is a set of elements related to the meaning that a user places on an artifact, including function and image. State space is a set of physical quantities generated when an artifact is in a given condition, and includes stress and acceleration produced when an external force acts upon an artifact. Attribute state is a set of elements that describe the geometrical and physical properties of an artifact (e.g., dimension and material). The circumstance is the environment where an artifact is used, including time, the user, external force, etc. Below is a description of the procedure of employing the Multispace Design Model in the example of eyeglasses.

Eyeglasses are a very useful tool in daily life, and its consisting elements can be organized using the Multispace Design Model as shown in figure 4. Here, "provide comfortable daily life" is placed in the value space, and "fits the user's face" and "correction of vision" is placed in the meaning space as meaning elements that realize value elements. Also, physical qualities that are influenced by circumstance are described as "constriction of the frame" and "adjustment of focus" in the state space. In the attribute space, physical elements that are not influenced by circumstance are described as "color" and "hinge". Finally, as elements of circumstance that influence the four spaces, "the user's preferences", "the user's age", and "the user's skeletal features" are arranged.

The relationship between these organized elements can be explained as the following. First, state elements emerge from the relationship between the attribute elements such as "color" and "hinge" and elements of circumstance such as "the user's age" and "the user's skeletal features". Next, based on the state elements such as "constriction of the frame" and "adjustment of focus" and the user's experiences, meaning elements such as "fits the user's face" and "correction of vision" emerge in the meaning space. Finally, the user will discover the value of eyeglasses as "provide comfortable daily life" from the meaning elements. Eyeglasses can be described by its elements and can be placed in the 4 spaces and circumstance in this way. By doing this, it becomes possible to organize the elements of a design object and comprehend the relationship between elements and design knowledge.

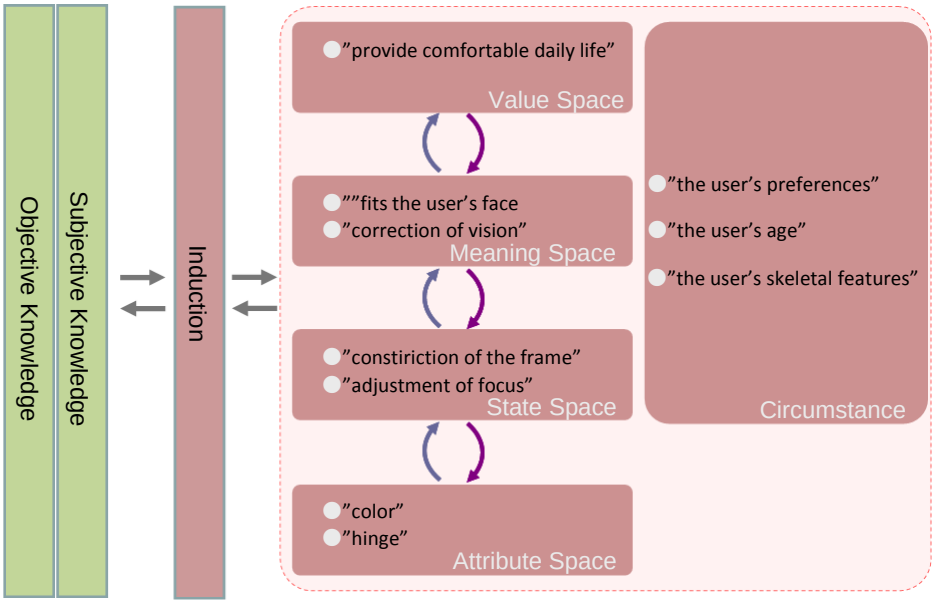

Figure 4: Elements of eyeglasses

3. CASE STUDY AND ORGANIZATION OF EXISTING VALUE GROWTH DESIGN CASES

3.1. Case study of existing Value Growth Design cases

3.1.1. Extraction of cases

The procedure of the case study carried out is shown in figure 5. To collect Value Growth Design cases, first, words strongly related to Value Growth Design, shown in table 1, were extracted. Second, artifacts, which exhibited the growth in value based on the extracted words, were collected via research on the internet and in documents. Third, related words were also extracted from these cases. Fourth, these related words were used to repeat the second step. As a result of this repeated operation, 84 cases were collected.

3.1.2. Selection of cases

Value Growth Design is a design that focuses on the change of value of an artifact from the point of purchase. Furthermore, the value referred to here includes composite values determined by an unspecified number of users and the surrounding environment. In this research, we analyze cases where a single user exists for a single artifact, and aim to consider composite values by expanding the results. From this viewpoint, out of the collected 84 cases, we selected cases which the point of its purchase is clear, cases whose value increases from the user's point of view, and cases where a single user could be identified. For example, a baseball glove corresponds to a single user, while the Tokyo Tower does not. Cases such as this were omitted at this stage. As a result, 14 cases were selected as Value Growth Design cases as shown in table 2.

Figure 5: Procedure of case study

Table 1: Words related to Value Growth Design

attachment	acquaintance	accustom	harmony	learning ability
customize	trust	time-passage	long-term	prediction
self-expression	taste	convenient	safety	...

Table 2: Selected 14 cases

AIBO	Paro	smart phone	car navigation	fountain pen	jeans	baseball glove
pongee	archer's glove	writing brush	leather shoe	lacquerware	copper-sheathed-roof	Nambu ironware

3.2. Organization of elements based on the Multispace Design Model and the Value Growth Model

3.2.1. Introduction of the Multispace Design Model

By organizing the elements of the 14 cases using the value space, meaning space, state space, attribute space, and circumstance, we are able to conduct the study from a unified viewpoint.

3.2.2. Observation of the change over time

The cases collected in this research are all involved in change over time. For example, the writing brush becomes accustomed to the user through repeated usage, enabling the user to write freely with their will. This is caused by the hair of the brush being strengthened through usage. Such characteristics can be seen in all the other selected cases, and it is considered that several phases exist in the process of a user using an artifact, in which their values grow.

3.2.3. Introdution of the Value Growth Model

In order to consider the change over time of the 14 cases, we introduce the Value Growth Model. Figure 6 shows the growth of value over time and the five phases of the Value Growth Model: value discovery phase, value realization phase, value growth phase, value establishment phase, and value tradition phase. In each phase, the practical value and spiritual value of an object change.

Period 0: Value discovery phase

The value discovery phase is when one discovers the value of an object or product through a brochure, advertisement, or trial period prior to purchasing. Since the user does not possess the object, the spiritual value mainly increases in this phase.

Period I: Value realization phase

The value realization phase is when a user uses an object or learns about its different functions. This is the phase when expectations and the actual usage of a product are reconciled, which lead to a significant change in an object's value. Due to the object's functions and usability, the practical value mainly increases in this phase.

Period II: Value growth phase

The value growth phase is when a user employs an object and becomes accustomed to its usage. The user also develops a sense of attachment to it. The value changes most in this phase,

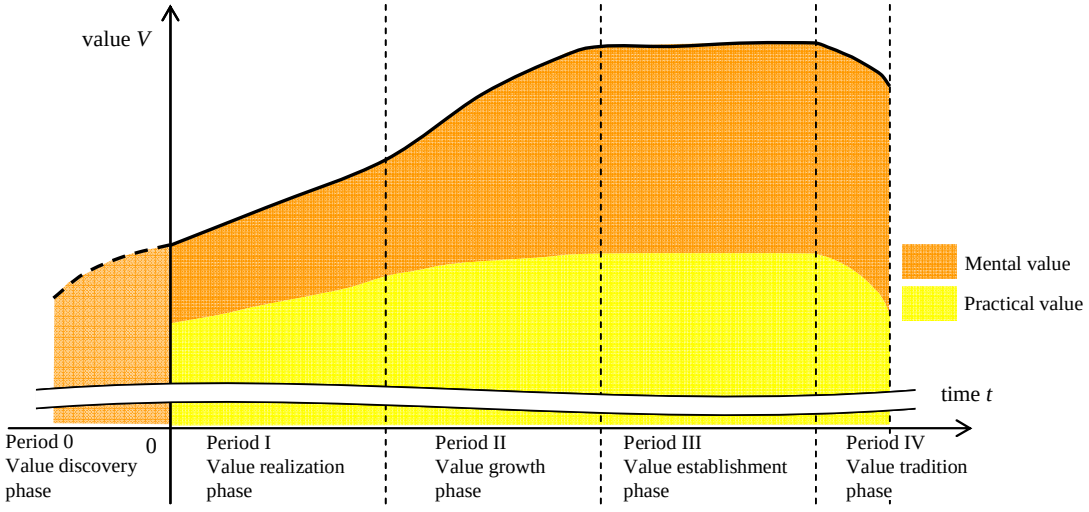

Figure 6: Value Growth Model

mainly due to the increase of spiritual value.

Period III: Value establishment phase

The value establishment phase is when the value on the whole eventually stabilizes. The user is able to obtain a stable value from the object. In this phase, the value that has been built up in the past phases is more significant than the growth.

Period IV: Value tradition phase

The value tradition phase occurs when the value of an object begins to decrease due to decay, and the object is replaced. An object is replaced, especially once it exceeds its life expectancy and when the value rapidly decreases. In this case, it is possible to transfer the value of the former object to the replaced object due to data transfer for example.

3.2.4. Organization of elements based on the two perspectives

Based on the Multispace Design Model and the Value Growth Model, the elements of each case were sorted due to the value space, meaning space, state space, attribute space, circumstance, value discovery phase, value realization phase, value growth phase, value establishment phase, and value tradition phase. While sorting, the possibility of each element's correspondence was considered by extracting elements from the descriptions of the artifacts and placing these elements into the corresponding spaces as shown in figure 7.

4. FACTOR ANALYSIS OF VALUE GROWTH DESIGN CASES

4.1. Cluster analysis

4.1.1. Introduction of means-ends

In order to clarify the patterns of value growth, we introduce the perspective of the means-ends of Value Growth Design. The means of Value Growth Design refer to bio-inspired technology and service technology, which are proposed to be effective in previous studies for the growth of value, which are the ends. The values that increase as a result of these means can also be divided into practical values and spiritual values. The details of this perspective are described below.

1. Practical values and spiritual values

The value elements extracted from the collected cases included practical values due to the object's functions, and also included spiritual values due to affection. The value elements could be divided into these two.

- examples of practical values
  "an indispensable information terminal of a traffic society"(car-navigation), "improvement of skill"(archer's glove)
- examples of spiritual values
  "healing the mind"(Paro), "originality"(jeans)

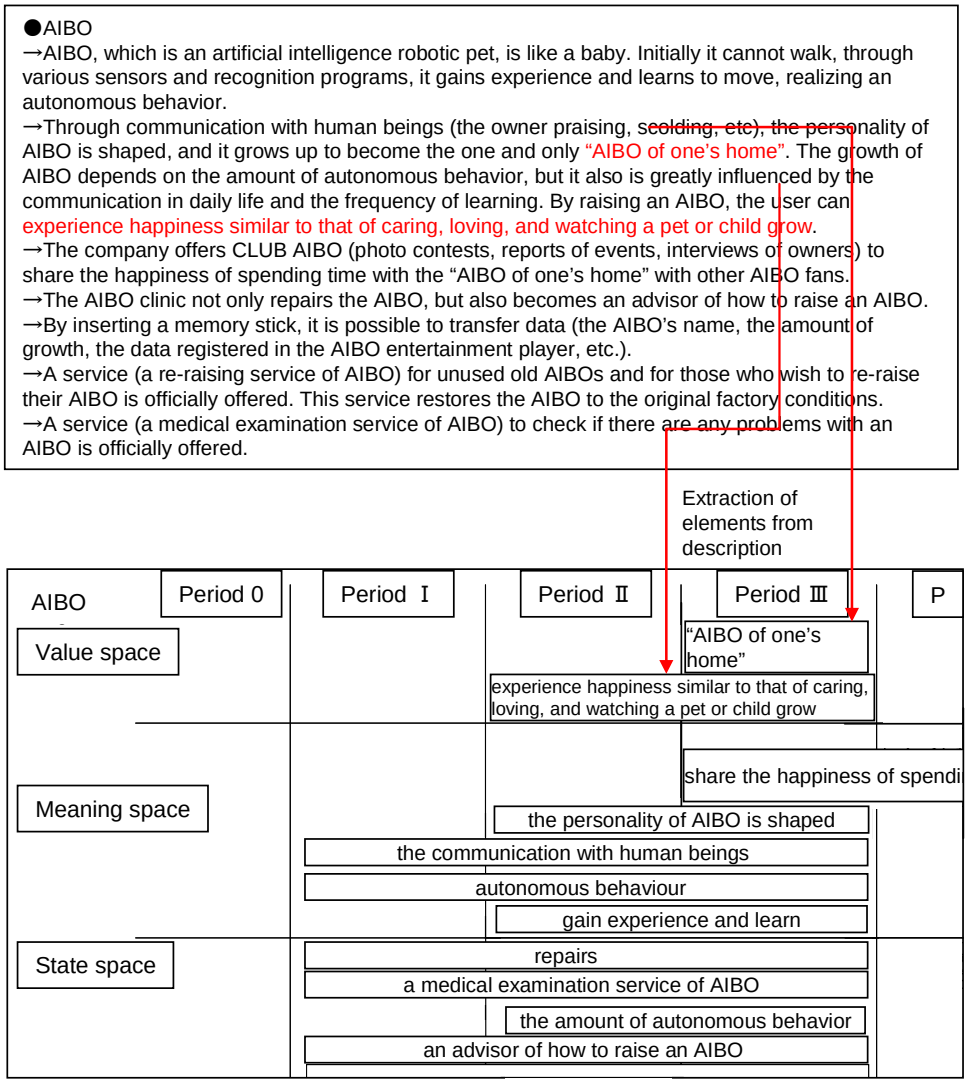

Figure 7: Organization of elements

2. Bio-inspired technology and service technology

The state elements extracted from the collected cases included changes occurring in the internal system and also in the external system of an object. The internal system of an object refers to the system composed of the elements of the object itself and its relationships, as shown in figure 8. The external system refers to the elements of the circumstances and its relationships. Bio-inspired technology and service technology act as causes of effecting change to these systems.

Bio-inspired technology aims to maintain and improve an object's value or functions by the improvement of the internal system through interaction between the external system. This follows

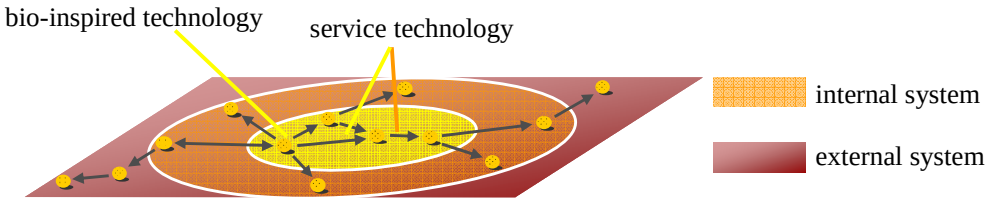

Figure 8: Internal system and external system

the system of living life. Service technology aims to maintain and improve an object's value or functions by applying service to the internal system and the external system of an object.

- examples of bio-inspired technology
  "growth speed of AIBO"(AIBO), "internal condition of Paro"(Paro)
- examples of service technology
  "appropriate care by the user"(leather shoe), "maintenance"(Paro)

Furthermore, service technology can be categorized into the following according to the target of change.

- change by the user (when the object changes due to the user)
- change by the artificial environment (when the circumstances change due to an artificial environment)
- change by the method of usage (when the circumstances change due to the method of usage)
  The cluster analysis was carried out based on the perspectives of 1 and 2.

4.1.2. Outline of the cluster analysis

To extract the features of value growth, a cluster analysis on the existence of elements in the four spaces and condition of the Multispace Design Model, the five phases of the Value Growth Model, and on the correspondence of practical value, spiritual value, bio-inspired technology, and service technology, was conducted. In this analysis, the Ward method (Nagata & Munechika, 2001) is used.

The Ward method combines clusters so that the sum of the squared deviation within a cluster is minimized. First, the squared Euclidean distance d_{ab} of cluster A samples a_1 and a_2 is determined as shown in formula (1).

$$d_{a_{12}} = \left(x_{a_1} - x_{a_2}\right)^2 \tag{1}$$

Here, x_{a1} is the coordinates of sample a_1 in the Euclidean space. Next, the sum of squared deviation S_l of cluster A is determined. When cluster A holds samples a_1~a_l, S_l is given as shown in formula (2).

$$S_l = \sum_{k=1}^{l} \left(x_{a_k} - \bar{x}_a\right)^2 \tag{2}$$

Here, $\bar{x}_a$ is the average of the distance between samples x_{a1}~x_{al}. Based on the Ward method, the clusters are generated and combined until all samples end up in one single cluster; the sum of the squared deviation within the remaining cluster is the minimum.

For each case, the existence of an element in a specific space for a specific phase was evaluated by two values.

4.1.3. Classification of cases based on cluster analysis

Figure 9 shows the results of the cluster analysis where the horizontal axis denotes the distance between clusters. Then the results were organized into four clusters, cluster A, cluster B, cluster C, and cluster D, as shown in figure 9.

The clusters differ by the presence of a value element, a meaning element, or a state element in period I, period II, and in period Ⅲ. Cluster A and B shows how value elements, meaning elements, and state elements all appear at an early stage. Although similar, the factors of cluster A and cluster B are different. For example, AIBO belongs to cluster A and possesses a learning function, enabling it to grow through interaction between its user. Smartphones, which is an example of

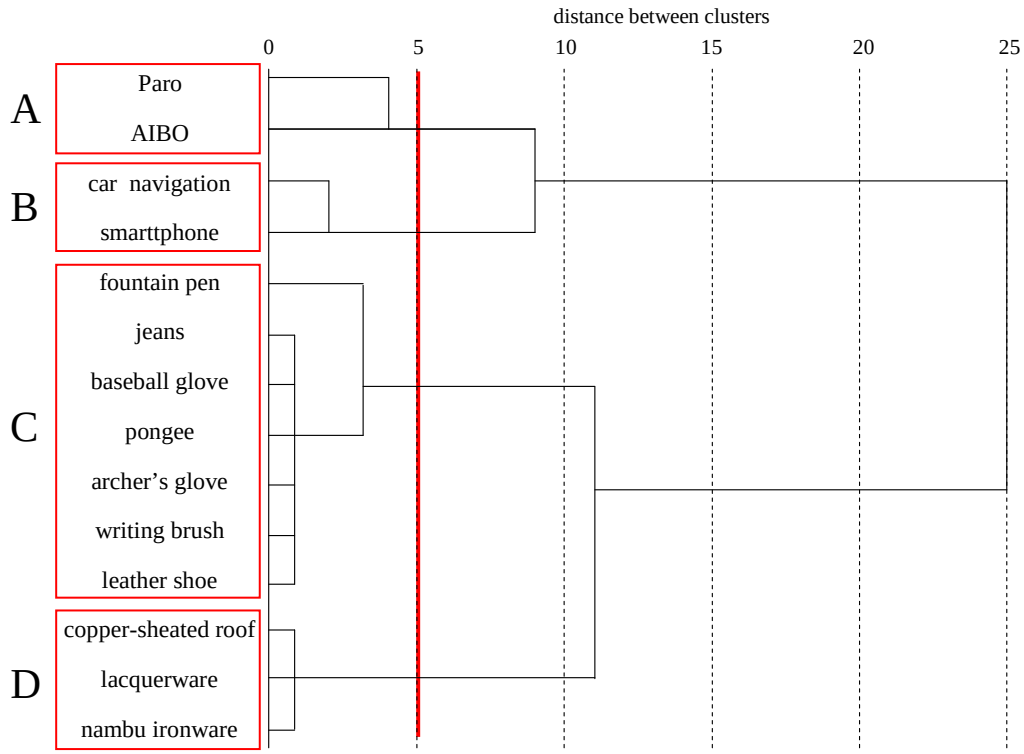

Figure 9: Cluster analysis results

cluster B, has various apps enabling its user to customize its functions to fit their needs. Therefore, cluster A is characterized by "learning", and cluster B is characterized by "customizing".

Cluster C shows how in phase I, value elements and meaning elements do not exist, while state elements exists, indicating that the value is just beginning to grow. Cases belonging to cluster C are leather shoe, writing brush, archer's glove, pongee, baseball glove, and jeans. The process of the user becoming accustomed to an object leads to the appearance of meaning elements and value elements in phase II. These changes are therefore due to care and repeated usage by the user, and cluster C is characterized by "accustomization".

Cluster D shows how elements do not exist in phase I, indicating that the value of the artifact grows suddenly, in period II. Cases belonging to cluster D are nambu ironware, copper sheathed roof, and lacquerware, which do not show a dramatic change during the early stages; consequently, phase I is absent. However, when these objects enter phase II, users are able to recognize the change through color or taste due to a chemical reaction caused by the surrounding environment. Therefore, cluster D can be characterized by "changing naturally".

4.2. Extraction of factors based on each cluster

The characteristics found in period I through period III is described as the following.

- period I

The user feels empathy due to elements such as "feeling of vitality" and "possess a learning function and takes action reflecting the user's senses", which mimic the features of pets. Users also are amazed to encounter elements such as "autonomous behavior", "able to follow latest trends". The user evaluates the object through senses of emotion based on these impressions.

- period II

The user evaluates the object comprehensively based on past experiences and elements such as "feel affection" and "preferences and personality is shaped" arise. This indicates how a

differential evaluation by the user is repeated and results in an integral evaluation.

- period III

The user is able to make full use of the object based on the accumulated information, and the surrounding environment is considered altogether. This appears in elements such as "stimulated conversation" and "update of map information".

When observing these characteristics, the perspectives below proposed to be effective in previous studies on each phase of the Value Growth Model may be valid.

period I-emotion theory

period II-integral evaluation and differential evaluation

period III-context model

In the emotion theory, emotion is created by amazement and empathy and the emotion theory effectively creates emotion. Amazement is due to an object’s novelty, while empathy is due to the user's understanding of a function.

Integral evaluation is due to a spur of the momentary evaluation. Therefore, objects are judged differentially at each time point. On the other hand, when an object is continuously used for a certain amount of time, reliability due to steady usage and affection due to long-term use both affect the object's value. Therefore, the value is evaluated integrally; that is, a product's value is built up over time.

The context model effectively explains the increase of shared information between two objects. Information shared within the context of the model is divided into two groups: a high context level and low context level. The high (low) context group consists of a large (small) amount of shared information. Thus, a user in the high context level group can effectively grasp the value of an object even if only a small amount of information is provided. An object's value may become stable as the shared information shifts from a low context level to a high context level.

As perspectives focused on the purchase of an object, the PEAM model proposed by Murakami(2012) describes the consumer's expectations towards a product and their emotional reactions due to purchase. There are also other proposed perspectives, but many focus only on a short time range, such as period 0 through period I. In this research, we consider the long time range of each object beginning from its purchase until its disposal. Thus, it is necessary to adopt perspectives that will cover a wide-ranged phase of value growth.

4.2.1. Factors of value growth in cluster A

We first consider cluster A, where value elements, meaning elements, and state elements all exist in period I(figure 10).

In period I of cluster A, the state elements are mapped to the meaning space, producing a meaning element. This is done by the user's original knowledge or new knowledge given from the external environment. For example, by looking at the "movement of the upper body and fins" of Paro, a meaning element "feeling of vitality" emerges based on the user's experiences or the information described in the operation manual. Moreover, in order for a value element to emerge by the mapping of a meaning element to the value space, a user must find some kind of value from the meaning elements. For example, the value element "healing the mind" emerges when the user finds the significance of meaning elements such as "interaction with people" or "possesses a learning function and takes action reflecting the user's senses". By applying the perspective of the

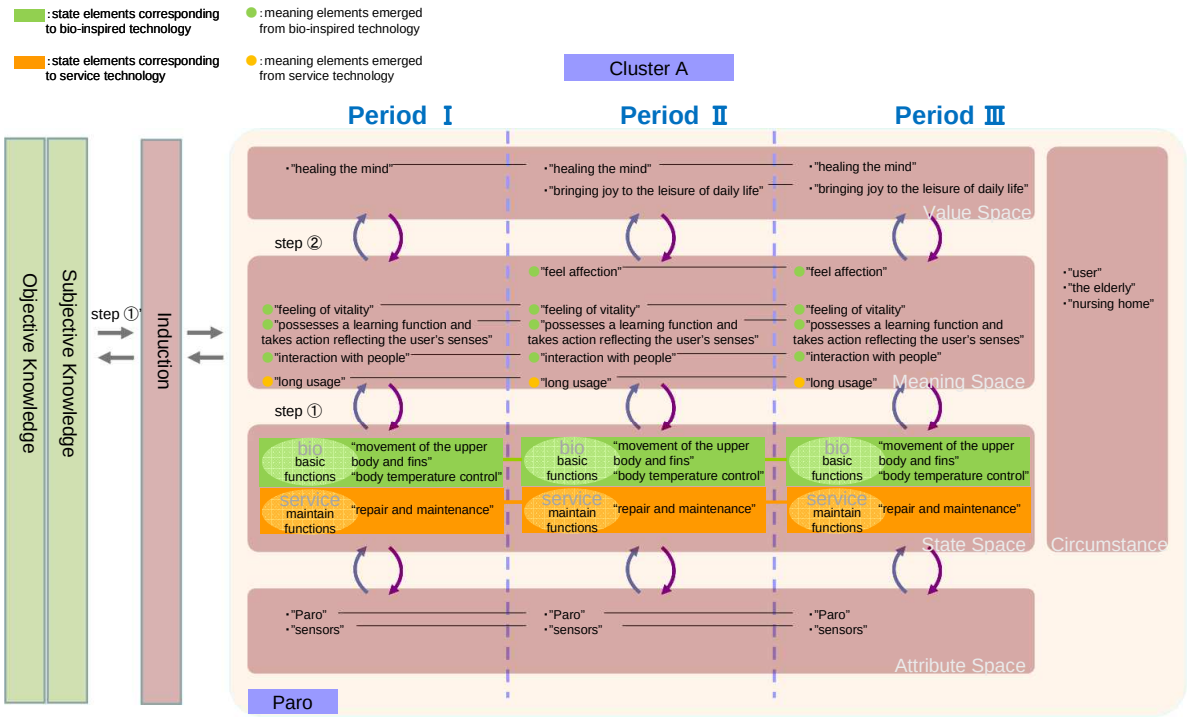

Figure 10: Elements of cluster A

emotion theory to the process, the following factors of value growth is proposed.

- the emergence of emotion due to bio-inspired technology and service technology ①

"Emotion emerges in period I due to the sense of empathy and amazement caused by service technology and mainly bio-inspired technology"

This mainly originates in the bio-inspired technology of AIBO and Paro.

In period II, value elements exist due to the existence of meaning elements and state elements, as in period I, but the process differs. In period II of cluster A, state elements which have emerged in period I and continuously exist in period II, and other state elements which have newly emerged in period II exist. Different value elements emerge from each state element. For example, "healing the mind" emerges from "interaction with people". This state element continuously exists in period II, allowing the same value element to emerge in period II. Opposed to this, "feel affection" a meaning element which newly emerges in period II, allows a new value element, "bringing joy to the leisure of daily life" to emerge in period II. By applying the perspective of integral evaluation and differential evaluation to the two processes, the following factor of value growth is proposed.

- the emergence of value due to differential evaluation

"Value increases in period II due to integral evaluation on the succession of value of emotion(memory)"

- the emergence of value due to integral evaluation

"Value increases in period II due to differential evaluation on the emergence of a new value"

In period III, state elements, meaning elements, and value elements all exist in all four clusters. Thus, all clusters reach the same state, which indicates how the value is stabilized by the growth of value reaching a steady state. By applying the perspective of the context model to the process, the following factor of value growth is proposed.

- establishment of value

"Value stabilizes in period III due to the continuous provision of value under small involvement of the user's knowledge"

In addition, the existence of a community consisted of users is also a difference seen between cases. A community is expressed by an element in the circumstances of an object. The meaning element changes in period III due to the change of circumstance caused by a community. Thus, the following factor is also proposed.

- sharing of value

"A new value emerges in period III due to mutual understanding and the sharing of information between users caused by the existence of a community"

4.2.2. Factors of value growth in cluster B

Figure 11 shows the elements in cluster B. In period I of cluster B, the following factor is proposed.

- the emergence of emotion due to bio-inspired technology and service technology ②

"Emotion emerges in period I due to the sense of empathy and amazement caused by bio-inspired technology and mainly service technology"

This mainly originates in the service technology provided by a company which realizes the object's bio-inspired technology.

In period II of cluster B, factors of cluster A can be proposed. For example, "evolving to match the user's tastes" emerges from "able to follow latest trends" of smartphones. This state element continuously exists in period II, allowing the same value element to emerge in period II. Opposed to this, "provision of accessories" a state element which newly emerges in period II, allows a new value element, "individual characteristic of the user" to emerge in period II. Finally, period III of cluster B shows the same features as those of cluster A.

4.2.3. Factors of value growth in cluster C

As shown in figure 12, in period I of cluster C, state elements such as "care" exist, but meaning elements and value elements do not.

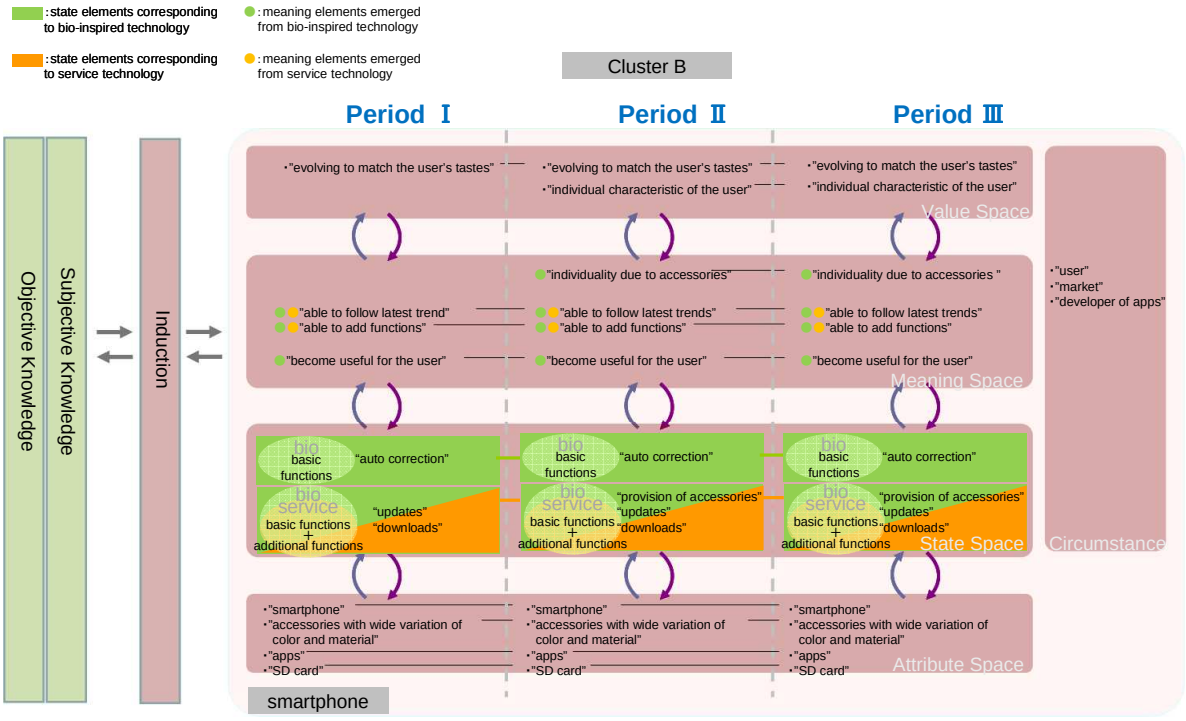

Figure 11: Elements of cluster B

The emotion theory applied to cluster A and B focuses on the meaning space and the value space of the Multispace Design Model(emotion is expressed by the multi-layer of the meaning space and the value space). Therefore, since cluster C does not correspond to the emotion theory, the consideration of its factors is done by focusing on the state elements.

The state elements such as "care" correspond to service technology. However, compared to cluster A where service technologies are also applied, meaning elements do not exist, and result in the absence of a value element. This indicates the existence of service technologies that lead to the emergence of meaning, and also technologies that do not. As explained earlier, service technologies can be divided into three according to the target of change. "a medical examination of AIBO" or "buildup of a database based on the users' experienced traffic jams and knowledge of short cuts", seen in cluster A, are categorized to "change by the artificial environment". On the other hand, "care", seen in cluster C, is categorized to "change by the user". In period I, the former allows the emergence of value, while the latter does not. Given the above, no factors could be extracted from this period.

In period II of cluster C, state elements, meaning elements, and value elements all exist. Like cluster A and B, state elements which have emerged in period I and continuously exist in period II, and other state elements which have newly emerged in period II exist. Different value elements emerge from each state element. For example, "something very important and personal" emerges from "care". This state element emerges in period I, and continuously exists in period II, allowing a new value element to emerge in period II. Opposed to this, "kneading" a state element which newly emerges in period II, allows a new value element, "improvement of archery skill" to emerge in period II. By applying the perspective of integral evaluation and differential evaluation to the two processes, the following factor of value growth is proposed.

- care

""change by the user" enables state elements such as "care" to continuously exist from period I to

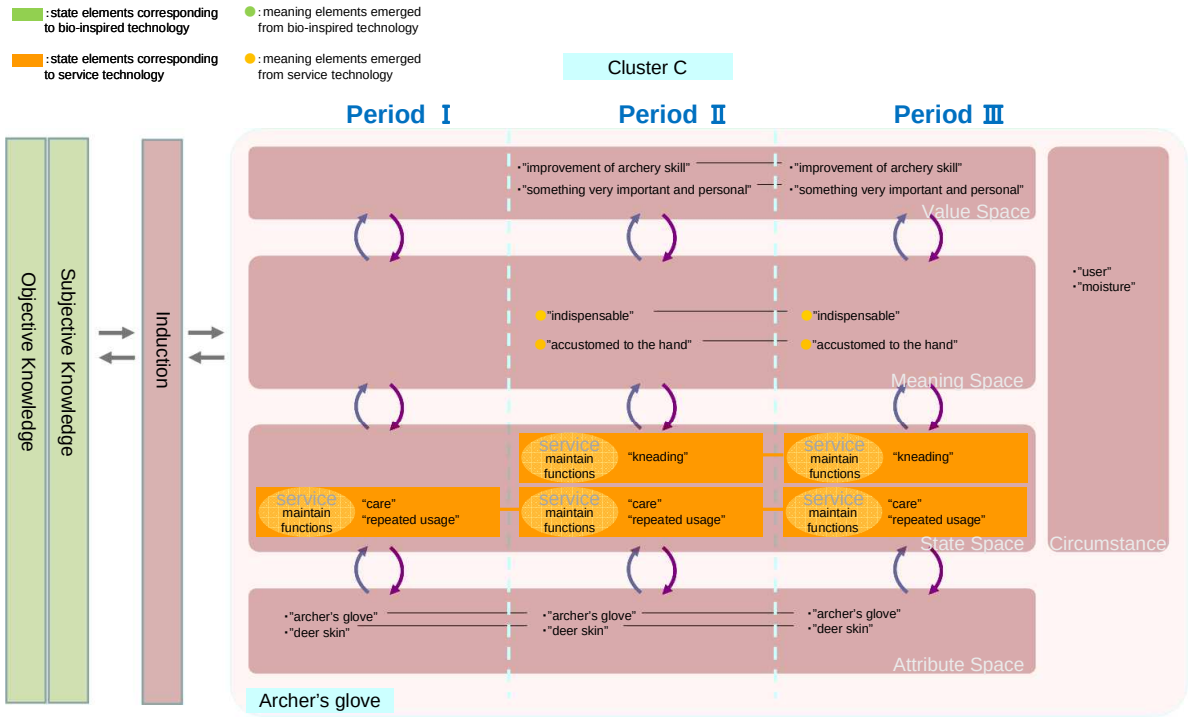

Figure 12: Elements of cluster C

period II. Value increases in period II due to affection and reliability caused by integral evaluation on the process"

- accustomization

"Value increases in period II due to change of the object's attribute elements caused by "change by the user ""

Finally, period III of cluster C shows the same features as those of cluster A.

4.2.4. Factors of value growth in cluster D

As shown in figure 13, in period I of cluster D, no elements exist. This is because no state elements exist which lead to meaning elements and value elements.

In period II of cluster D, the sudden emergence of elements in the state space, meaning space, and value space is characteristic. For example, the value element "good for the health" emerges from the state element "ferric ions are produced". Compared to the process of the emergence of value in clusters A, B, and C, this process differs in that it is affected by its circumstances. In the example of nambu ironware, elements such as "water" in the circumstances which exist from period I are strongly involved in the process of change in state. By applying the perspective of integral evaluation and differential evaluation to the process, the following factor of value growth is proposed.

- natural change

"Value increases in period II due to change of state caused by the accumulation of the influence of the natural environment"

Finally, period III of cluster D shows the same features as those of cluster A.

4.3. Factors extracted from each cluster

To summarize, a total number of nine factors were extracted from the four clusters, and are listed below.

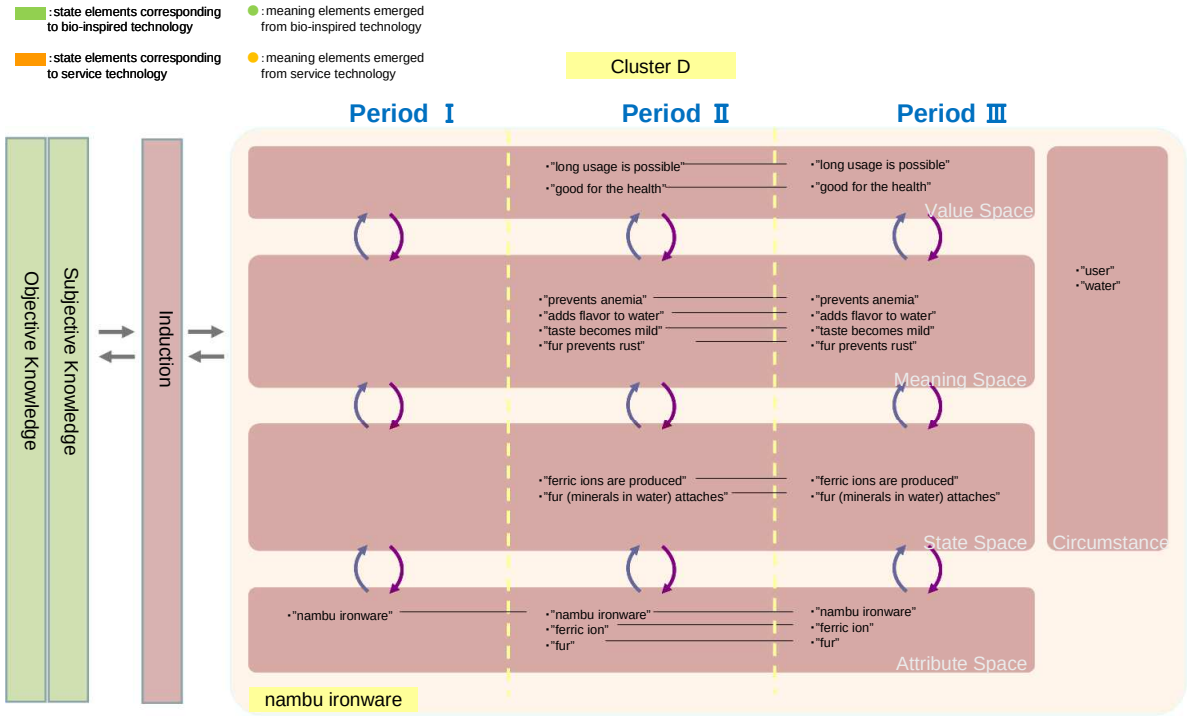

Figure 13: Elements of cluster D

- the emergence of emotion due to bio-inspired technology and service technology ①
- the emergence of value due to differential evaluation
- the emergence of value due to integral evaluation
- establishment of value
- sharing of value
- the emergence of emotion due to bio-inspired technology and service technology ②
- care
- accustomization
- natural change

These factors were extracted from different clusters and represent different patterns of value growth.

5. CONCLUSION

To clarify the factors of value growth, this paper conducted a case study of existing Value Growth Design cases and a subsequent cluster analysis to extract the factors of value growth. As a result, cases showing value growth from various genres were collected, and four patterns of value growth appeared. A detailed investigation of these patterns produced nine factors of value growth. In future research, the relationship between the factors should be analyzed in detail because their relationships may clarify the value growth mechanism, and become contributory to the application of Value Growth Design.

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