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What is “What’s the Design”?

Toshiharu TAURA Kobe University
Hideyuki NAKASHIMA Future University-Hakodate
Yukari NAGAI Japan Advanced Institute of Science and Technology

Recently, the term “design” has been used in various situations. We recognize it not only in the case of Industrial and Engineering Design but also in Cooperate and Career Design. An explanation for this trend can be found in the essential beauty that lies in the concept of design rather than in the design process itself. With the desire to break through social stagnation and the hopelessness that overshadows us, the focus is on people who have the ability to compose and create. This phenomenon is especially significant in the manufacturing field such as in industrial production.

So far, a principal topic in the manufacturing field has been *how to make things*. However, technology has matured and society is satisfied with the abundance of products ; thus, the focus gradually shifts to *what to create*. At the same time, environmental issues are significant and the social system needs to be restructured. When our social problems increase in number and complexity, looking at or considering things from the perspective of the notion of design or the ability to design appears to be the key to solving these problems.

The word “design” has been used mainly in the context of industrial and engineering design. We believe that the fundamental meaning of the notion of design should be understood in its broad sense.

Thus, we refer to the way of looking at or considering things from the perspective of the notion of design or the ability to design “*the Design.*” Furthermore, we want to formulate an answer to the meta-level question, “What is the essential meaning of *the Design?*”

The purpose of our activity is to define *the Design,* systemize it as an academic discipline, and finally, provide society with a practical methodology for *the Design.*

We are not in a rush to establish the definition of *the Design* because we recognize the essence of *the Design* not in the definition itself but in our activity of defining what *the Design* is. By clarifying and defining what *the Design* is, we will uncover an important meaning in the diversity of perspectives and motivations that lie in the action of clarifying *the Design.* If we try to define *the Design* in the existing stream, we must select definitions from those that already exist or revise those definitions, and not take for granted that the essence of *the Design* will be preserved if a definition is selected.

We approach the meaning of *the Design* from the following two aspects.

The first aspect is the perspective from which we discuss *the Design.* We can identify various perspectives such as mapping, self-expression, semantic generation, problem solving, and hypothesis generation. But why do so many perspectives exist? If the essence of *the Design* can be found in its diversity, do we not need to discuss the nature of the diversity of the perspectives in order to capture *the Design?*

The second aspect is the motivation to discuss *the Design.* Why do we want to capture *the Design*? These motivations may also be diverse, for example, intelligent curiosity to understand the nature of *the Design,* social motivation to establish a method for *the Design,* and so on.

In other words, what we want to do is to design *the Design.* To achieve this, we need to investigate the meaning of *the Design* and determine *the Design* at the meta-level. On the basis of these considerations, we chose the title “What is ‘what’s the Design’?”

In this special issue, we intensively approach *the Design* from various perspectives. The objective is not to find common features between the perspectives of different disciplines but to collect and accumulate the perspectives and motivations to capture *the Design.*

We were able to invite the authors of 11 articles related to the following fields.

Philosophy−Michio ITO
Cognitive Science−Masaki SUWA
Architecture−Haruyuki FUJII
Engineering Design−Koichi OHTOMI
Industrial Design−Takeshi SUNAGA
Linguistics−Kazuko SHINOHARA
Artificial Intelligence−Mark D GROSS
Natural Language Processing−Eiko YAMAMOTO

Information Science−Hideyuki NAKASHIMA (Co-Editor)
Art and Design−Yukari NAGAI (Co-Editor)
Design Science−Toshiharu TAURA (Co-Editor)

We formed a community to discuss *the Design,* and five meetings have been held in the past two and a half years. The discussions in this issue are based on these meetings.

The articles can be divided into two categories.

The first category concerns a meta-level discussion on *the Design.*
Michio ITO tries to present a meta-level analysis of the question related to the meaning of *the Design.*
Hideyuki NAKASHIMA discusses this issue from the perspective of “design of design” and indicates a new direction for *the Design.*

The second category discusses each standpoint.
Yukari NAGAI et al. discuss *“what the design is”* with the aim to capture the ideal design through comparisons with art, especially by identifying the notion of motif, abstraction, etc.
Masaki SUWA argues that meta-cognition is useful for learning and teaching *the Design.*
Haruyuki FUJII characterizes *the Design* from the perspective of constructive nature, by focusing on the nature of law and polysemic dualities.
Koichi OHTOMI introduces an approach to assess the worth of a consumer product through an example on product sound quality.
Takeshi SUNAGA explains that “what’s the Design” can be clarified by actually doing *the Design.*
Kazuko SHINOHARA uses language games to capture the nature of creativity from the perspective of designing the games.
Mark D GROSS argues that the approach to the science of design lies in computational thinking, and that technological changes in our world today are edging us toward a profoundly computational view of designing.
Toshiharu TAURA et al. define design creativity as a combination of the artistic design process, which is based on design insight, and the systematic design process, which is based on design outsight.
Eiko YAMAMOTO et al. introduce an analysis of the deep impression of artifacts in order to gain a fundamental understanding of *the Design.*

We would like to bring together all these perspectives and approach *the Design* in one step.

Editors
Toshiharu TAURA
Hideyuki NAKASHIMA
Yukari NAGAI

What’s What’s the Design? –Meta–analysis of the question of the design–

Michio ITO
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Abstract

This paper tries to inquire the meta-level analysis of the question of the design. This analysis leads to ask about “what is asked about the design?” or the structure of the question of the design. Designs are variously talked about and have only family resemblance. However, what we ask about will decide the directions of the knowledge about the design. A philosophical question about the design can escape our ordinary everyday-understanding and expand our horizon.

1. The type of question

We ask many questions, and there are many types of questions. For example,

“Where is the station?”

“I want to know a way of the demonstration of Pythagorean proposition. How can I know?”

“Who should be given the Nobel Prize?”

“For what should I spend my money and energy? ”

About the first two questions :

If we ask a person the way to the station, and the response is, “I don’t know.”, then we ask another person and so on. If we happen to meet a person who knows the way to the station or the way of the demonstration, then the questions are over. To ask another person is meaningless. It is same as the investigation of a book or internet.

The third question :

If we ask a person, and we get one answer, the answer is not still decisive. To answer such a question we collect answers and consolidate them. This is called ‘social or group decision making’ like the voting system. And it has the characteristic of not asking “facts” like the way to the station or the way of demonstration, but asking about “evaluation” or “value”.

The last question :

This is the question about the philosophy of life, or how to live, about which we ask several persons but do not follow one decisive answer or do not consolidate them. This is also concerned with evaluation or value. The question is an ethical problem concerning how I should live. The word “should” is often used as an ethical term [1].

When we ask, “What is the design”, what type of question does it belong to? Of course, it does not have a decisive answer. Indeed, many designers propose themes or opinions, and we can collect and abstract them, but others may deny or refuse them.

And the question “what is the design” seems to ask about the fact of the design. But it implies implicitly “what is a <good> design?” We may not ask “what is the design” giving <not good> or <bad> designs.

But here, when we ask what the goodness of the good design is, then we are perplexed. Some designer’s responses are function, usability, or beautifulness and so on. Dieter Rams, for example, gives the 10 design theses [2] :

Good design is innovative. Good design makes a product useful.

Good design is aesthetic. Good design makes a product understandable.

Good design is unobtrusive. Good design is honest.

Good design has longevity. Good design is consequent down to the last detail.

Good design is environmentally friendly. Good design is as little design as possible.

This thesis is understandable or interpretable for some designers, but others not. Or the nature of goodness could not be totally enumerated and could not find a united opinion. Nevertheless, we can distinguish good designs from bad ones. Besides, what we will pay an attention is that value-goodness is ambiguously arranged. Is it intrinsic to the articles or artifacts? Does it belong to the process of the designer’s behavior? Or does it exist in the environment including designers, users and articles? From the point of view of language usage, meta-language is needed to analyze the word “goodness” and systematization of its usage. It may lead us to analyze the goodness of the design.

Well, when we ask “what is a design”, at the same time, we ask “what is a good design”, and then we fall into the “naturalistic fallacy”, borrowed from ethical term, which reduces ‘value’ to ‘fact’. But pure description of ‘fact’ is, indeed, an ideal and abstract logical description. We can divide ‘value’ and ‘fact’ ideally, but in fact both are continuous.

More important is to awake to implicit meaning of the question “what is the design”. When we ask “what is the design”, we have in mind a “good design” as a clue.

2. The formal structure of the question

To ask “what is the good design” as clue, what is it?

Martin Heidegger analyzes the formal structure of the question at the beginning of “Being and Time” before asking what Being is [3].

In presenting the “formal structure” of the question, Heidegger claims to rely on the structure that is common to all questions and that includes three constitutive moments.

In every question, we can distinguish three moments :

1) “that which is asked about,” **Gefragtes** ; we intimate it, but without knowing anymore what we are putting into question ;

2) “that which is interrogated,” **Befragtes**, that is, that to which our question is addressed ;

3) finally, there is “that which is to be found out by the asking,” **Erfragtes** : what is being asked, what one wishes to know when one poses the question, the meaning or point of the question-in short, the question behind the question.

When we ask, “Where is the station?”, then “That which is asked about” (Gefragtes) is how to go to the station. “That which is interrogated,” (Befragtes) is, for example, a person whom we happen to meet and our question is addressed. “That which is to be found out by the asking,” Erfragtes, is, the concrete information to the way to the station, for instance, “Along the street to north on foot in 5 minutes.”

Another question : “Does this music sound beautifully?” That, which is interrogated,” (Befragtes) is ‘this music’. And we ask, “Does it sound beautifully?” [4] We answer, for the time being, “It sounds beautiful”, or “It does not sound beautiful.” This question is a question about ‘this music’ and asks “Does it sound beautifully?” We can also ask,” Who composed this music?” or “Who plays this music?”, and these questions are different from the question : “ Does this music sound beautifully?” We can ask many questions about this music and many points of view enable these questions. The question comes from the point of view of the beauty, that is, the question has a point of view. And it seeks an answer.

We can ask the question “Does this music sound beautifully” from the points of the beauty and can answer it, of course, according to listeners the answer is controversial.

Then we ask, “ What is the beauty or the beautifulness?” So, ‘beautiful things’ are different from ‘the beauty’. If we give ‘one’ music and say “This music is the beauty”, we fall into a ‘category mistake’ [5]. To the question “What are the beautiful things”, we can give roses or some landscapes. But these are not the beauty itself. When we ask the beauty, we ask further the point of view. We can hardly answer it, nevertheless, we can draw a distinct between the questions “what is the beauty” and “what is red”, because the beauty and the color are distinguished.

Finally, we ask “What is the music itself?”

This is also the question that bothers us. ‘The music itself’ is neither concrete, tangible things like beautiful things nor abstract one like Idea (Plato) or the beauty. We may give some beautiful songs and say “These songs are music”, but we cannot say “This song is the music itself” nor “The music itself is the song you now listen”, unless we give a rhetorical expression.

In addition, how can we distinguish music from merely arranged sound? Music composed with a computer, though players often claims the intention of composing, we cannot deny it as music.

It will be impossible to check over the ‘extension’ of existing music and define the ‘intension’. We also consider the implicit ‘context’. The same noise made in a street, which is played in a concert hall, we can be taken not as noise but as music, and try to understand the intention of the player or the composer.

In *Being and Time* , when Being is asked, an entity (Dasein) will serve as the primary example to be interrogated in the question of Being. So here, analogically we may take a means to claim a typical music or prototype music. Prototype, which is often used in Cognitive Science. This question is about “that, which is interrogated,” (Befragtes). We address a question to prototype or typicality and try to answer what the music itself is.

However, there are many genres of music, as symphony, jazz, rock and so on. It may be true in each genre to have a typical one, but how can we imagine the typical music itself?

Rather, such condition remind us of the concept’ family resemblance’. Wittgenstein introduced language-games to understand language metaphorically as games [6].

Consider, he says, the proceedings that we call ‘games’. I mean board-games, card-games, ball-games, Olympic Games, and so on. What is common to them all? Tennis and jacks have a ball in common. There is no ball in hopscotch, but there are “jacks”. There are no jacks in jump rope, but there is hopping. Leapfrog is child’s play (but there is no equipment, e.g. no ball, jacks or rope). In volleyball there are no racquets, but there is a ball and a net. Badminton has no ball, but there are racquets and a net. There is no net in bridge and no playing cards in tennis, but bridge and doubles tennis are played by teams. There are no teams in solitaire, but there are playing cards. There are no cards in chess. Still, just as we cannot give a final, essential definition of ‘game’, so we cannot find “what is common to all these activities and what makes them into language or parts of language” [7]. Here, Wittgenstein rejects the general explanations, and definitions based on sufficient and necessary conditions. To know the games, we begin to play one game and only this we can do, and cannot make the definition. But to play one game (using language) leads us to know the game (understanding meaning of language), or overlapping relationship of games, that is, family resemblance. When we ask, “ What is the music itself?”, then Erfragtes, which is not a definition, but to listen to music leads us to know the meaning of the music and there are only family resemblances. Of course there is no entity of the music.

Well, back to the question : What is the design?

The dimension of the question belongs neither to the dimension of the things which are designed nor to the dimension of the beauty or the goodness. Same as the dimension of the question : “What is the music itself”.

We cannot reach the nature or definition of design by abstraction. We look at buildings, telephones, cars, etc., but cannot abstract the definition from artifacts. Giving designed articles to answer what the design is makes a category mistake.

Here, it is pointed out that we must consider Befragtes, “that which is interrogated,” will decide a direction of the questions and answers, and further a point of view. Above said, when we ask the design, we mention good design. But Befragtes is not only good design.

In ordinary studies we may investigate early researches as Befragtes. But we could address a question to designers or designed articles. We point out again that Befragtes will decide a direction. If we ask to designers, so we will focus on the way of design, the intention of designers, or the creativity of design, the control of design function or process. And we will argue the design from these points of view. So we will hardly discuss without the notion such as intention or control.

Well, among the demonstrations of the existence of God, there is a famous argument, the argument by design, about which William Paley proposes ‘watchmaker analogy’ in his *Natural Theology* (1802).

When we walk around in a field and we trip over a stone, we ask “Why is this stone there?” Perhaps there was a stone for a long time. However, when we walk around in a field and found a watch, we easily see that this watch is fabricated by an intelligent watchmaker who has an intention and designed it. So, just like a watch when we look around the nature, we see that this elaborated nature could be designed by the intelligent creator, God. If you do not prefer the word ‘the design of God’, behavior of the nature of ‘evolution’ could be designed.

Nowadays behavior of animals concerning evolution is sometimes likely to be explained with the notion ‘affordance’ that J.Gibson introduced in *The Ecological Approach to Visual Perception* in 1979. Therefore we could interrogate ‘affordance’ to understand the design. Then, not the designers’ aspect to design functional artifacts on the basis of behaviors assumed to be most appropriate or suitable, but we begin to observe and analyze action possibilities of users. Because action possibilities are latent in the environment and in relation to an actor, we pick up in one special environment some actions, and along the environment and action we may design without any stand-outing artifacts. In this case, for the design it is important to observe how actors derive information-value from the environment while relating perception to action.

How do we relate to the world and perceive it is a clue to understand the design. When an action to an artifact or a natural thing in an environment is done, it is deemed to be ‘original’ or ‘creative’, though the artifact or the natural thing may not be deemed original or creative. So, the originality or creativity of the design needs to be reconsidered.

After Heideggerian term ; the first thing that we encounter in the world is, Zuhandensein (Readiness-to-hand), which is equipment or tool, the designed thing for some purposes. And the knowledge we have about using equipment is in relation to other equipments. We are in the relationship of equipments or tools. A behavior ‘writing’ has the knowledge about paper, pen, and ink and so on. And we implicitly consider ‘time’ (Mit der Zeit rechnen). Ordinarily we do not consider the duration for which a hammer can be used, but sometimes take care for the duration of the paper, which may be tone. In this case, to discuss the design, relationship of designed articles and time is focused.

These various arguments remind us of the notion ‘family resemblance’, mentioned above. Perhaps we cannot make the definitions of the design based on sufficient and necessary conditions. To understand the meaning of the design we will begin to design or use the designed articles and in the process of circulation of knowing and using, in other words, theory and practice, we need to continue asking, “What is the design?” The direction in the network of family resemblance that the design will make, may be decided with Befragtes, that which is interrogated.

Here we have to pay attention to the following ; could the study of the design be possible? “Being is variously talked about” (Aristotle), and the study on Being is approved as Ontology, but could the study of the design be possible?

Indeed design is talked about from various points of view along Befragtes. Or it may be discussed as engineering design or as an artistic design. The design is variously talked about and will not make any species. If the intention of the designer functions well on the artifacts, or a natural thing gives a function to the actor, it is called good design, and the meaning of the good design is so understood. The design is variously talked about, but we colud imagine the study of the design that treats the matters which is related to the design.

3. The meaning of the question

A Question is an ordinary speech act, but its end is not only the answer. Indeed, ordinary question or a scientific question will give priority to seek the answer. The answer is a reality and the answer fixes a certain matter. But a philosophical question presupposes interaction between reality and possibility.

The philosophical analyses of the structure of the question teach us that the question of speech act has a power to construct. The consecutive question (*Fragen*) can make our thinking constructive, or escape our ordinary everyday-understanding and expand our horizon.

Acknowledgments

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Design of Constructive Design Processes

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1. Introduction

The purpose of this article is to formalize (design) a design process as a constructive process. We discuss "design" in its widest sense : If we divide design into two categories, grand design and specific design, this article is on the former. Designing a new system/mechanism or a new architecture is within our target, while designing a specific machine or an individual building is not.

In the above sense, a design process is a creative or constructive process. A design process starts from a concept or description of a desired function and tries to find a system that realizes it. Therefore, we will first talk about constructive processes before we define design and formalize the design process.

2. The Sciences of the Artificial

Natural sciences, physics in particular, are the study of the laws governing our world. It starts from natural phenomena and tries to reveal the underlying mechanisms which created the phenomena. In other words, natural sciences start from already existing phenomena or mechanisms and divide them into their parts. They are called analytic in this sense. Descartes [1] is one of the earliest who formalized the method for those sciences : Given a complex phenomenon, we divide it into simpler sub-components and tries to understand the simpler parts and relationships among them ; The process is repeated until each sub-component is simple enough to reveal the law that governs the component.

The study of artificial things is somewhat different. First of all, the direction of construction of artificial thins is almost reciprocal [+1] to analysis of natural phenomenon. We start from simple elements and combine them to form more complex artifacts. The key problems are the selection of the initial components and the way they are combined. Note that neither of them is given in contrast to natural science where all components are given *a pri ori*. Formalization of the constructive processes is the main purpose of this article and we will come back to this issue in section 4.

Harvard Simon named the field as "the science of the artificial" [2] contrasting it to the science of natural phenomenon. He claims (a) that everyone designs who devises courses of action aimed at changing existing situations into preferred ones, and (b) that schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all concerned with the process of design.

There are several synonyms to "construction". "Creation" and "synthesis" are among them. We avoid using "creation" since "creative process" has another connotation related to "creativity" or "innovativeness". "Synthesis" may be a better candidate since it is usually contrasted with "analysis", for example as in "analysis by synthesis". However, when the word is combined with "design", "synthetic design" may have connotation related to synthetic materials or chemistry.

The reason we choose to use "constructive" is existence of "constructive mathematics". According to Stanford encyclopedia of philosophy [3], it is defined as follows :

> *Constructive mathematics is distinguished from its traditional counterpart, classical mathematics, by the strict interpretation of the phrase "there exists" as "we can construct". In order to work constructively, we need to re-interpret not only the existential quantifier but all the logical connectives and quantifiers as instructions on how to construct a proof of the statement involving these logical expressions.*

3. Design

We define design as construction of a new system that has some preferred function or feature. To think about a new function or feature is also (part of) design. "New" is simply defined as something that did not exist before. Under this definition, construction of a new system without intent is also

[+1] As we describe later, construction and analysis are not precisely reciprocal each other. Our study shows that analysis is a part of constructive process.

called design. Animals are designed through natural selection processes without any intention.

Similarly, intentional unintentionality, decision of no action, is also a design. For example, bonsai, Japanese tree shaping art, is one form of design, but the decision of doing nothing and let the tree grow is another form of design. There is also some intermediate stage where only some of environmental parameters, like lighting or room temperature, are manipulated. They are not direct manipulations of tree shape but an indirect one leaving some room for the nature to take over some part. The hand of nature is an essential part in ceramic or pottery art, and also in calligraphy. There are also many other kinds of spontaneous art where contingency plays important roles.

Furthermore, "verbalizing design is another act of design" [4]. Verbalization is a step toward making the process explicit and shareable. We will focus on this in section 5.

We should also distinguish grand design, design of a type from specific design, design of individual entities. Designing a new type of objects that did not exist or thought about before is a very difficult and creative process. But when a design method of a type is known, then there can be a procedural method to design one instance of the type. The former is an instance of grand design and the latter is an instance of specific design. Designing a rotary engine, for example, is creative while improving its parts is rather routine work of designers.

When we consider grand design, a totally new design may only be found through (random) generate-and-test. But once a new type is found, we can formalize it define a new type. A design of the type is then procedurally (algorithmically) applied for individual designs of many instances. There may be many objections to the view that grand design, or innovation, is achievable only through generate-and-test. Many researchers believe it possible to teach, enhance and systematically support creativity. Before we engage in this discussion (at the end of section 5), let us formalize constructive processes.

4. Constructive Process

We are interested in construction of a new system.

It is generally understood that construction is a reciprocal process to analysis : Analysis is from the whole to the parts and construction is from the parts to the whole. This may sound obvious when we think about plastic model kits. When we buy a kit, the whole set of parts are prepared and we connect them together.

However, in reality, we found it different. First of all, when we design a new system, necessary parts are not known yet. Only after we have enough knowledge on the new system, we can identify necessary components and make it a routine work. To have knowledge, we have to analyze the system. Here comes the second point. Analysis must be a part of construction (Fig.1.) [5]. Thus we can say that analysis is a part of construction.

Let us take an architect as an example. When an architect is given requirements (desired features) of a new type of a

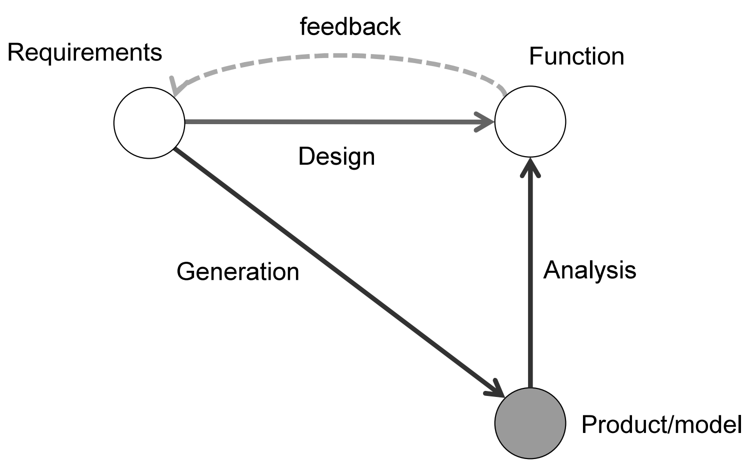

Fig.1. F-diagram of constructive processes

building, he cannot directly design the perfect one on a paper for the first time. Trial and error loop is unavoidable. He first constructs a model [+2]. He then analyzes the properties of the built model. If the result of the analysis satisfies the original specification of requirements and constraints, the design is complete. However, this rarely is the case. There are some differences from the original specification. Then the whole cycle recurs by changing the model to meet the specification. Sometimes, the original specification may be updated reflecting some findings from the model.

Note also that F-diagram applies to the process of theory forming of natural scientists as well. Model generation can be mapped into experiments, and a specification is mapped into a hypothesis that must be proven through experiments.

Actual systems we construct are usually complex. A system is complex when it is build (and therefore should be understood) of multiple layers of sub-systems. For example, a building consists of multiple floors (or stories), which in turn consists of rooms and corridors, which in turn consist of doors, walls and ceilings. A wall consists of some combination of base materials. They may form an arch to support heavy constructions or they may form some other architectural structure.

We are trying to formalize construction of such multi-layered complex systems by extending the F-diagram. To understand the concept of multi-layered system, we found the concepts of noema and noesis [6] useful. Suppose one is playing a piano.

There are two levels involved : one is the conceptual level of music, and the other is physical level of play, including motion of the player and the piano. The player first plans to produce certain music. This plan of the music is in the conceptual level, called a *noema*. Since the concept is not realized yet, we call it a *future noema*. He then begins to realize the music by playing the piano. This activity is called a *noesis*. His activity interacts with the environment, including the room and audience, and actual music is produced. The player then listens to the music he produced. The conceived music is called a *current noema*. The player must readjust his plan (music to be produced) according to the generated music. And this loop continues.

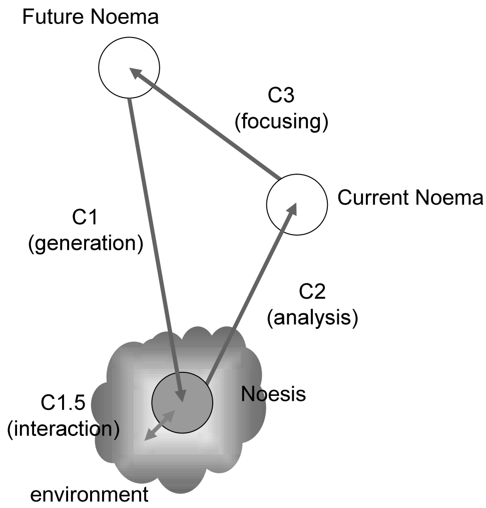

Fig.2. FNS-diagram

The following is a constructive loop in general explained in terms of noema and noesis (Fig.2.) :

(C 1) A noesis is generated from a future noema.

(C 1.5) Generated noesis interacts with the environment and produces some phenomena. This interaction with the environment is both the source of new emergent property [+3] and the obstacle that makes desired result difficult to obtain.

(C 2) Generated phenomenon, larger than noesis, is then analyzed to produce the current noema.

(C 3) Since obtained current noema is different from planned future noema, the future noema must be readjusted. This is the most difficult and creative process. A new future noema is created and the loop recurs.

Existence of (C 1.5) interaction with the environment is a very important phase in the process. If this interaction is small and virtually negligible (as presupposed in experiments of physics), then we can take some deductive approach to run the constructive loop. If all related parameters are known and numerical, then we can take optimization method formalized in operations research. However in reality, this interaction cannot be neglected. To be worse, we do not know related set of parameters beforehand. We cannot circumscribe related elements or limit the affected region. It is only after the analysis phase (C 2) that we know related parameters and

[+2] The “model” here should be understood in a very broad sense. It may be a small scaled model or it may be a real building. Anything but the final version falls into this category of models, and it even covers real buildings with people actually living or working in it.

[+3] As we described in section 3, this is where “hand of nature” plays important role in ceramic or pottery art, or in calligraphy.

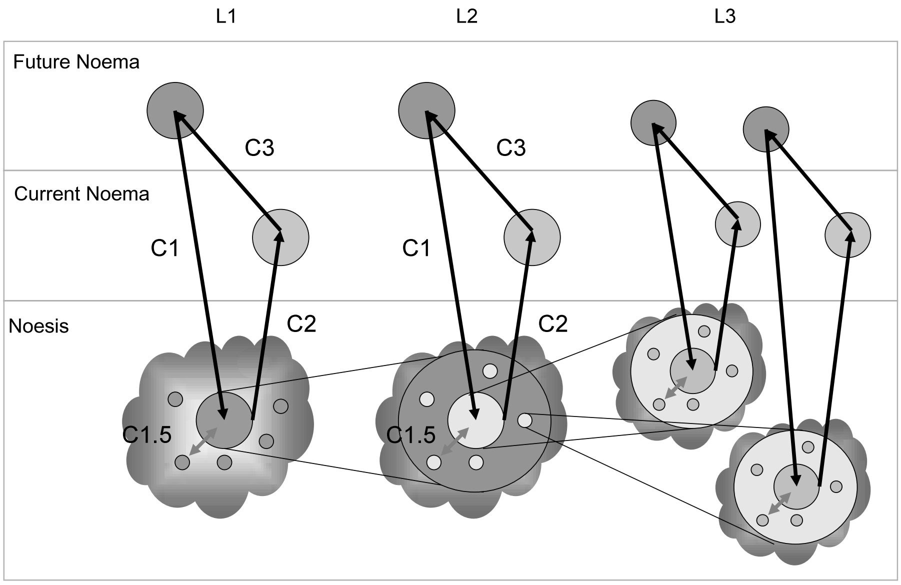

Fig.3. Multi-layered FNS-diagram

consequences. The problem is well known in AI community as the frame problem [7].[+4] This is one of the reasons we claimed (at the end of Section 3) that only generate and test is a feasible strategy for innovative design.

Because of C 1.5 unwanted interactions may occur. In that case, we have to change our plan, the future noema. How? Study of complex systems tells us that any small change in the future noema may cause unbounded amount of change in the noesis. Therefore, adjustment on the future noema may have to be repeated until we get desired current noema. This process may result in complete change of the conception scheme and produce totally different noema. We believe that there is no systematic procedure for C 3. Only a loop of generate (C 1) and test (C 2) is possible. C 3 defines what to generate next from a wide range of alternatives. Thus we call C 3 “focusing”.

In the above description, only two levels, music level (noemas) and play level (noeses), are involved. If the system consists of more layers [+5], we will see a hierarchy of nemeses and corresponding noemas. Fig.3. shows multi-layered FNS diagram. Left-hand side shows a higher layer and right-hand side shows a lower layer. A noesis in the higher layer is decomposed into several parts in the lower layer and each of them has its corresponding noemas. In the diagram, we focus only one (in L 2) or two (in L 3) of them. Other parts become part of environment surrounding and interacting with the noesis in focus.

Let us consider the same case of playing the piano as an example. L 1 is the “music” layerl (conceptual music as a noema and actual play as a noesis). Actual play in L 1 is then decomposed into the piano and the player in L 2. From the viewpoint of the player, the piano is a part of the environment here. The player is further decomposed into his brain, the body, arms and fingers in L 3. Noeses in all layers as a whole form a tree structure connected by “part-of” relationship.

Note that they are systematically connected only in the noeses level. Noemas for each layer have looser connection. They may or may not be independent each other. In other words, each layer corresponds to different cognitive levels and they follow different rules. Description of music and description of body movement are in different description layers and there are no logical or causal relations between them : The behavior of the upper layer cannot be reduced into the behavior of the lower layer. Yet, there is some relationship between them. We call it “vertical causality” [8]. It is called vertical because the

[+4] It is worthwhile to point out that this problem is found when they tried to design intelligence machines. The problem could not be found in the long tradition of either analytic science or philosophy.

[+5] We use “level” to differentiate noema and noesis. We use “layers” to distinguish different conceptual layers of the objective systems.

relationship connects different layers. We do not precisely know the relationship or we do not have any descriptive language to define the relationship.

Vertical relationship nevertheless is one of important one in design. When a designer wants to realize some function, and when that function cannot be straightforwardly implemented by a noesis within the same layer, then the designer must go to a lower layer. A simple example is driving a car. If you want to run fast through a curved mountain road, you cannot stay within "driving" layer. You have to go down to the lower layer to plan (a) turning wheels, (b) select gear position, (c) applying proper amount of gas, or (d) stepping on the brake pedal. The relationship between the fastest path through the mountain road and your driving activities (a) to (d) is not clear. This relationship is what I call a vertical causality because it can be talked in the same vocabulary of usual causality − the car skidded "because" you applied too much acceleration, or "to" run the car smoothly you should be delicate on the acceleration pedal, etc. You may have to practice or try some new technique because vertical causality is hard to understand or realize.

5. The Design

What is the essence of the activity called design (let us call the essence "the Design")? This is a meta-level question on design − design of design. The theme of this special issue is one further up in the *meta* hierarchy − What is "design of design"? What do we have to do to understand design of design? Let us consider some characteristics of the Design.

First of all, the Design and the technology to support its realization are complementary each other. They cannot be separated. A design is meaningless if it cannot be implemented using existing technology. Research and development of technology should also be guided by good design. Of course there are bottom-up characteristics in basic research and they should not be neglected. Nevertheless top-down guidance is equally important.

The author's research background, for example, is information technology (IT). The research of the author focused on new design of social systems that are only achievable with full use of IT. It is different from computerizing existing system. A new system must be designed with regard to the full capacity of IT.

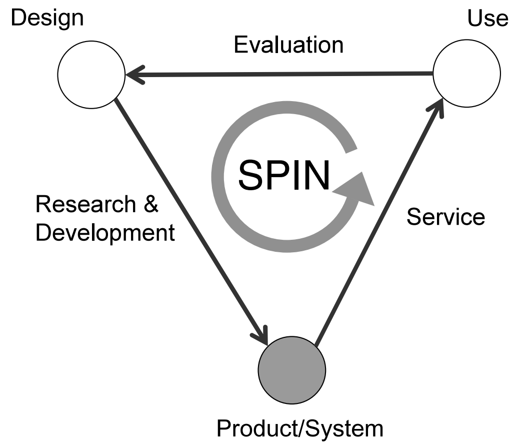

Fig.4. The service loop

Secondly, the Design should be a part of a service loop [+6] of the designed product (Fig.4.). It forms a develop-service-evaluate loop. Or in case it requires further research, construct part is further decomposed into research-construct-evaluate loop. Therefore, design process can be understood as one of constructive processes formalized as our FNS-diagram. Let us use an example of airplane. Boeing or Airbus (designer) designs and then develops a new airplane. An airplane (product) is owned and operated (service) by airlines like JAL and ANA. Their service is evaluated by users. This evaluation unfortunately includes occasional accidents. Experiences from service are fed back to design of safer and better airplane.

Let us review the loop from a larger perspective. Technology produces alternatives, humanity selects and puts it into service, and science evaluates the result.

The third point is on the methodology for the Design, in particular innovative designs [9]. As we formalized in section 4, the Design is a constructive process. Transition C 3 of Fig.2. is where creativity is called for. If there is a systematical method, like optimization method for specific designs, then it can be achieved somewhat mechanically. This kind of optimization method is also teachable. However, on the other hand, if a new jump is required, we have only two ways : (1) rely on random generation, and (2) rely on human intuition, which we know nothing about. Either solution cannot be taught systematically. True innovation is just an outcome of a random jump.

[+6] "Service" here means to actually put the product into use.

6. Summary

We claimed that the Design is a constructive process and formalized the process. The Design and the technology to realize it are complementary each other. There is no royal road to the Design, but a loop of generate and test, which we formalized as FNS-diagram. Finally we claimed that design should be a part of a service loop.

Acknowledgment

Concepts and ideas presented in this article are mostly the result of a long discussion with Haruyuki Fujii (Tokyo Institute of Technology) and Masaki Suwa (Keio University).

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Design Motifs : Abstraction Driven Creativity

− A Paradigm for an Ideal Design −

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Abstract

This paper examines design motifs. We focus on the importance of the internal perspective of a designer as a factor that drives the design process ; as we consider that a motif drives a design's creativity. Two types of abstraction processes in design (human-driven abstraction and generalization) are addressed by studying creativity in both design and art. We discuss the difference between design, art and their mainstay in time. An ideal design is expressed as the real meaning of 'a real design activity', also as the issue to be studied for identifying a design, elaborating on 'what design is'.

1. Preface

In this study, we discuss the central issue of what a design is and how people approach this issue. 'What design is' has been a fatalistic issue as a target from both studying approaches : designing and investigation (namely, 'research').

We begin our argument with 'creativity' in design for identifying a creative design. Creative activity is, as a matter of fact, often explained as a characteristic of humanity. Creativity is an issue that should be investigated in cognitive science since it is the foundation of all creative acts, i.e. 'creativity plays a vital role in a host of human activities. It can enrich our lives when it reveals itself in soothing or exhilarating music, etc. People explain creativity as 'it can bring us new tools' and 'it can provoke advances in science' [1]. 'Creative thinking', which involves stirring creativity is also discussed because 'it is crucial as we adapt to our changing world' [2]. Creativity is usually considered as a person's ability to produce something new and unexpected [3]. However, people also realize that there are many different levels of human creative acts [4]. Perhaps, we can appropriately classify personal creative acts into three categories : mundane creativity, productive creativity, and excellent creativity [5]. Mundane and productive creativity are suitable for problem solving, but excellent creativity involves (formulation and re-formulation processes) and activated by 'creative thinking' [+1].

The scope of the discussion in this paper is on excellent creativity, particularly in design. In previous studies on creativity, creativity in design has been defined as producing the concepts of 'really original' products [6]. Thus, the definition of excellent creativity in design can be considered as the ability and/or process of producing original products, which are novel, useful, and unexpected [7]. However, this is only an external viewpoint on creative acts. Viewing design from an external perspective enables explaining its structure by adopting models of systematic processes, i.e. problem solving processes [8]. Thus, for a long time, the notion of viewing designs from an external perspective has contributed to the accumulation of our knowledge for understanding design by adopting a problem-solving framework [9-10]. We obviously support this established perspective. For discussing the creativity of a design, we suggest that it is necessary to develop another perspective on design by 'creative thinking' from an internal perspective. The suggestions from the current studies rethink the vision and viewpoints ; i.e. senses for having another type of viewpoints from previous science 'constructive informatics' that discussed by Nakashima [11], also the ability of switching inner and outer perspectives for designing by Taura et al [12]. The above-mentioned suggestions affirm that setting a viewpoint involves a significant power for achieving more creative process in design. We feel that these viewpoints can be represented as 'motivation' and 'motifs'.

2. Designing from an Internal Perspective

Exploring the issue of 'what design is' itself involves undertaking acts that are highly creative and activated by internal energy. It begins with comprehending 'what design is'

[+1] Distinguishing creative thinking from productive, it is understood as a process of high quality thought including problem formulation, for example, inventions in science and creative work in art. Productive thinking is considered as a process for a given problem.

through various studies. Moreover, Cross explained that creative design activity appeared to be 'intuitive' because it appeared suddenly, and 'this is what characterizes creative design as an exploration, rather than a search' [13]. In order to explain the characteristics of a creative design, we emphasize on the internal energy that stimulates excellent creativity, which can be considered as a driving force for the process of designing. To explain internal energy, it is necessary to observe the process of design from an internal perspective. Probably, a desire to understand 'what design is' becomes an eternal motive of design. Therefore, it is necessary for us to argue what causes the emergence of a motive.

In this paper, we first discuss about the motivations behind designs from an internal perspective. Next, we overview current design studies to reorganize the key aspects for research on design in order to raise several issues. Further, we address the motives of design from an internal perspective to respond to the raised issues and characterize creative design.

2.1. Motivation for Producing a Creative Design

Why do people design? In discussions elucidating design, it is usually explained as the activity of people to make products (in other words, 'artefacts') for some purposes [14]. Critically, according to Simon [8], design has been explained as an 'action aimed at changing the existing situation into a preferred one' [15]. Thus, designers were considered as innovators or reformers who helped in producing social improvements. Probably, the wishes or desires of designers to change the world led them to be a designer in the first place and presented them with newer challenges. However, in design research, the importance of motivation is always noted but not explicitly mentioned in the design process. We are afraid that motivation is a hackneyed word ; indeed, the motivation for a design has a double meaning. External motivations, such as 'the purposes' of a design, present one meaning. The 'wish to change the world' is one of the external motivations. The other meaning refers to the intrinsic motivation, and this presents the more important meaning [*2] [16]. Since curiosity is suggested as the 'the biggest factor for motivation' [17-18], intrinsic motivation is the main power for producing a creative design. With regard to creativity, it would be better if the notion of motivation (especially the intrinsic one) is defined as a 'drive' to avoid confusion. A sense of 'drive' implies the energy behind the driving force in design. A design process as a voluntary creation can be expressed as a creative process engaging with a person's internal feelings that drives the person based on his/her intrinsic motivations [*3]. Based on the viewpoint of an internal perspective and intrinsic motivation (namely, 'drive'), this study attempts to clarify the issue of 'what design is'.

2.2. Three Aspects of Design Research

First, we overview the current issues in design research in order to specify the points of discussions to clarify 'what design is'. Design can be objectively expressed as a process. As described above, thus far, design processes have been studied by adopting a problem-solving framework from an external perspective. In recent times, design processes have been viewed differently from merely problem solving process, by adopting the internal perspective. There are significant issues in previous researches on design that have discussed the identification of design features in a more subjective manner. They have covered the following three aspects : (1) designing is a practice, (2) design produces artefacts, (3) design exists in the society. Since each of these three research aspects has examined recent designs, we review each aspect with regard to the trends of current studies.

(1) Practice

One important aspect of designing is viewing it as a 'practice' [19]. 'Learning by doing' is often valued for studying a designing process. The interesting aspects of a design can be understood only after experiencing it. In design research, 'knowing designs by doing' was highlighted to analyse its distinct features in observed design activities [20] or by reporting it through empirical studies such as 'action research' [21]. There is some truth in these viewpoints. Their claim appears to be that the important steps of acquisitions (i.e. awareness, schematic knowledge acquisition, knowledge transfer, and so on) of design involving embodied knowledge, including the tacit knowledge of people, are related with experiences [22]. Thus, practice is likely to be an essential experience for people to learn design and to become design experts. In current studies, how to formulate design goals is an important issue in understanding the processes of design learning and the

[*2] The two reported types of motivation are : (1) intrinsic motivation, which occurs when people are internally motivated to do something because it either brings them pleasure, or they think it is important ; (2) extrinsic motivation, which comes into play when a student is compelled to do something or act in a certain manner because of external factors.

[*3] See 'Design Creativity' by Taura and Nagai in this special issue.

process of gaining expertise [23-24]. However, why people (students) became enthusiastic with regard to design activities was not explained. This is our first doubt.

Commendably, practice is also pointed out as necessary for people engaging in creative acts. Edmonds and Candy have developed 'practice-based research' from the viewpoint of creativity [25]. They address the concept of the creative relationships between participants and art systems for interaction design [26], identifing a creative engagement between art systems and participants as new dimension of HCI.

Since practice-based research provides knowledge of creativity with regard to its intrinsic motivations, we develop our discussion to the researchers' dual motives for elucidation and for producing design (or art). Discussion on how does practice in designing differ from art practice is another issue and will be described in the last section of chapter 3.

(2) Producing Artefacts

Another aspect of designing is highlighting its outcomes. A number of design researches surveyed design outcomes, for example product designs. Plastic arts of such products provide a considerable amount of information on learning how to make good designs ; however, there are more important aspects in understanding designed objects. By analysing designed objects, we may be able to understand designers' thought processes and how they decided the forms and mechanisms of those objects. As noted by Visser, design can be employed for understanding the human mind, that is, for understanding 'cognition' ; thus, studying a design implies knowing the artefact as a 'cognitive artefact of designing', referring that Simon's 'designing' is formulated in 'creating the artificial' [27]. Although Visser emphasized on the importance of research on real design activity, we suspect that studying 'real design' does not imply studying the work of real designers. Innovative objects are an example of a remarkably successful outcome of the creative process. The process to obtain such successful outcomes is often called as an 'innovative design' process [*4]. Although some successfully designed objects represent attractive beauties (colours, shapes, and symbols), there are limited as designs in 'styles' (plastic arts). Moreover, artefacts represent functions as well. Thus, many studies pointed out that the embodiment of usefulness in designed objects is also necessary [26]. However, there is a remarkable missing link between designed objects and a designer's criteria for a novel design. How can we explain that designers are aware of the criteria for a novel design? Do they learn the criteria for a novel design through their experience? Of course, they can learn these criteria from previous designs by studying designed objects. On the other hand, these criteria limit the designers' performances in adding some features to the previous designs. Therefore, we suspected the presence of contradictions between the external and internal criteria of the designers. This is our second doubt with respect to the previous researches.

(3) Design problems

Further, the notion of viewing designing as a feature of a civilization has arisen only recently. Ulrich explains the design process as 'human endeavour' to find design problems in a situation and then to change it into a better situation [29]. Circulation models represent the relationship between designers, users, and the society. Krippendorff claims that the users' requirements based on their experiences by using artefacts represent social needs that keep up with the times [30]. Design is believed to be a social act to introduce changes. In other words, designers probably find their target for designing from users' requirements or from society. Knowing users' experiences and social needs are believed to provide a hint for future designs [31]. Scenario-based designs (SBD) and persona-based designs (PBD) have developed designs by including participants (users). Thus, the notion of a design problem is considered as an expanded design space in a society. The designers' contributions may be considered as community service from this viewpoint. Thus, service design reforms the framework of a design model into a wider developed one−similar to a business model. To understand design in a society, design education should be developed based on cross-disciplinary collaborations [32]. A view of the 'design for society' gives a 'raison d'être' to both designers and users for sharing the world, enables the opening of doors to knowledge related to other disciplines, and provides a sense of responsibility towards sustainability. However, our third doubt is whether 'observing the outer world (humans in a society) is the only way to determine a design problem?' Where we find 'a design problem' is the central issue in understanding 'what design is'.

[*4] Sometimes, people confuse 'design inspired innovation' and the innovative process with product development, including its elaborations. People tend to pay attention to the trials of product developments, without paying attention to the newness of the idea itself. In this study, we discuss the characteristics of a creative design, apart from the process of product development.

2.3. Designs Motifs[+5]

In order to answer the above-mentioned doubts on previous design research, we propose our view that 'approaching the notion of "what design is" would provide a deeper understanding of the motives of design'. In other words, internal perspectives and criteria form the motives of design, and they drive people to study design (designing or research).

Fig. 1 expresses the setting of our view and the framework of research on creative design. On the basis of this framework, we attempt to address the above-mentioned issues. With regard to the first doubt, we infer that the motivation to promptly practice a design lies in not only the design goals but also in the intrinsic motivation that is the centripetal force that drives design learning through practice. With regard to the second doubt, we suggest that the discussion on how innovative (novel) ideas are generated must be investigated to understand creative artefacts. With regard to the third doubt, we infer that designers have an internal criteria for their designs if they aim at understanding 'what design is'. Further, we propose 'design motifs' of a design that drives the design process and leads to the creation of a design from an internal perspective.

To discuss designs motifs, we found some different types of potential motifs. Rosenman and Gero proposed a diagram of processes involved in creative design to illustrate knowledge-based models of creative design via the classification of the different types of design processes : combination, mutation, analogy, and first principles [33]. Combination has been also reported as one of the examples of creative thought that evokes creative leaps in a design process [13]. A process of concept-synthesis in design has been focused upon as it leads to generating a novel design idea [34-35]. The phenomenon of the concept synthesizing process in design shows that a process can be driven without any external goals. For example, a process of synthesizing a new idea of animal from the existing animals is explained as paradigm model [12]. We focused on factors that evolve a design process. From the internal perspective, 'abstraction' is found as another type of design motif that activates design processes.

In the next chapter, we argue about abstraction in design as a motif and how it influences the creativity of a design, beginning with some recollections of art and design.

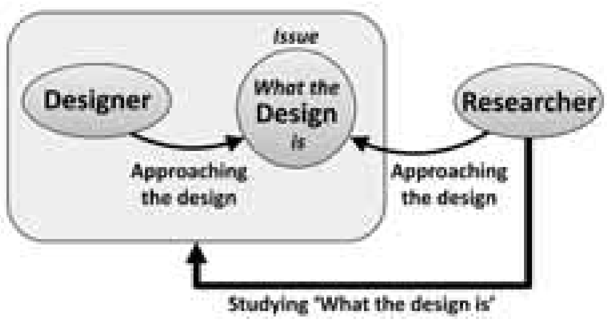

Fig.1. Study approaches to design

3. Abstraction

In the early twentieth century, modern styles were expressed as art and design movements. One movement called as 'Abstraction-Creation' expressed the new world in abstract shapes[+6]. Usually, people recognized art and design as styles (namely, plastic arts). However, its creation process, rather than its appearance, is much different from that of previous art. Thus, artists began designing systematic paintings and sculptures. In this paper, we discuss abstraction power as if it naturally inhabits minds, and it is deeply connected to the problem of how we approach 'what design is'.

3.1. Abstraction Process

The ability of abstraction is explained as 'the quality of being abstract' that implies 'a general idea not based on any particular real person, thing, or situation'. 'The state of thinking deeply about something and not paying attention to what is around you' is the second formal meaning of abstraction. In technical terms, 'the action of removing something from something else' is also called as abstraction, because it is the process of being removed from something else in order to extend to 'abstraction'. Abstraction is defined as follows : (1) preoccupation, (2) the process of formulating generalized concepts by extracting common qualities from specific examples, (3) a concept formulated in this way : good and evil are abstractions[+7].

The abstraction process has illuminated mechanisms of human thought, in particular of the creative thought concerning 'analogical reasoning' [36]. The structure of mental mapping

[+5] The notion of a 'motif' is used in the same meaning as 'motive', that is, 'a reason for doing something, one that is hidden or not obvious' ; moreover, motif is similar to 'theme', 'subject', or 'conception', in this paper. 'Motif' is also the origin of the term 'motivation'.

[+6] see Abstraction- Creation', in The Oxford Dictionary of Art.

[+7] 'Abstraction' (a) a general idea not based on any particular real person, thing, or situation ; the quality of being abstract ; (b) the state of thinking deeply about something and not paying attention to what is around you ; (c) the action of removing something from something else.

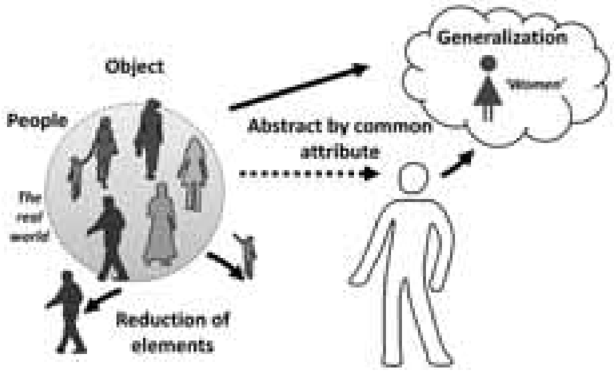

Fig.2. Process of generalization in abstraction

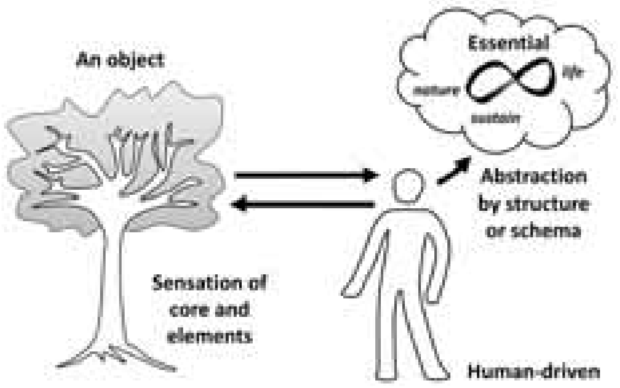

Fig.3. Process of human-driven abstraction

was explained as a process of abstraction and knowledge transfer. However, what evokes abstraction is not yet clarified.

Since we believe that 'what design is' is a key issue to understand creative thought, we focused on the process of abstraction in design. The abstraction process perhaps plays the role of a driving force for design. To formulate a concept, extracting the essence by capturing the nature of the object is the main process of abstraction. To determine a common quality within various objects, people remove separate objects during the extraction process. We consider abstraction as a human ability for capturing the essential quality with entireness of an object.

To be sure, it is necessary to inductively capture a common denominator of the features in order to extract common features. This is referred to as 'generalization'. However, generalization is possible without being preoccupied with objects, and it is not a human-centred abstraction process (Fig. 2). Generalization helps in simplifying the representation of objects. To introduce the human-driven abstraction process, Figure 3 illustrates a human abstraction process (e.g. abstract painting) activated by a drive (intrinsic motivation) from an inner perspective. On the basis of this human driven abstraction process, the designers discover what 'a design should be' in essence, namely, an ideal design.

Notably, based on the above classification, human emotion can be also considered as an abstracted feeling without any logical operations[+8]. The basic power to extract the nature of the objects−which is called as 'sensation'−has been discussed in psychology ; it views the inherit phenomena within an object rather than its surface attributes [37]. However, the ability of extracting the inherent nature of things or objects only acts as perception, and it does not represent excellent creativity. The ability of designing is required to create a new art. For example, a painting in 'abstract expressionism' is not representative of art, but it expresses not only human emotions but also abstraction of the object (the world)[+9]. The motif of a painting is extracted from a relationship between the self of an artist and the world from the viewpoint of the artist, resolving the issue of 'what the art should be'.

It is believed that the ability of abstraction typifies human thinking. We have argued that the abstraction process and the ability of abstraction in design are required in every piece of art, especially in the case of a designing a creative piece of art. Abstraction can be considered as a strong motif for achieving excellent creativity both in art and design. The sentence 'nothing emerges from nothings (zero)' represents an aspect of human creativity. It implies that 'new ideas, whether wondrously creative or merely unusual, are almost always constructed from the building blocks of prior knowledge' [38][+10]. These creative features occur in both art and design and are also related with the process of human-driven abstraction. Although there are many similarities between design and art at the excellent creativity level, we now consider the characteristics of design.

In the next section, we investigate the design abstraction process to distinguish design from art.

3.2. Comparison between Art and Design

Leonardo da Vinci had argued that the significant contributions

[+8] See 'abstraction' in The Encyclopaedia Britannica regarding 'Souriau, E. (1947) *La correspondance des arts,* Flammarion'.

[+9] The dominant movement in American painting in the late 1940 s and 1950 s. (see 'Abstract Expressionism' , in The Oxford Dictionary of Art).

[+10] 'Picturesque' is a feature of art. Strains and spots of such modern painting regard to the memory of the things which reflected on eyes. This imagination process can be viewed as a discovering process by an interaction between the self and the object in a world. Such a process occurs in design, in particular in sketches in the early stages of the design process.

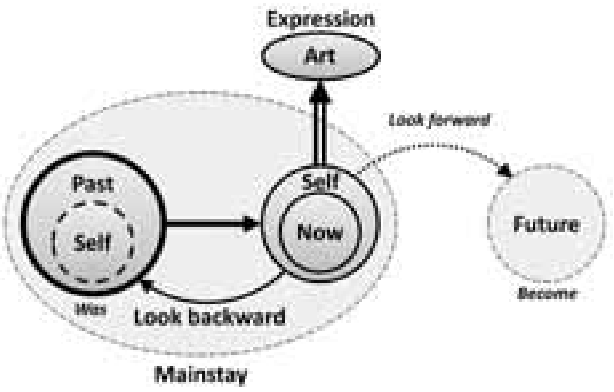

Fig.4. Mainstay of art motif

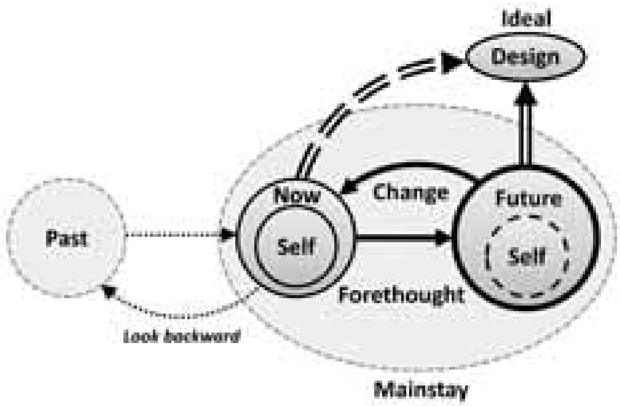

Fig.5. Mainstay of design motif

of art activity were not only in the form of skills related to handwork but also in the form of a human approach to realize the world [38]. Therefore, the formative art activity involves both 'handwork' as well as 'mind-work' at the same time. Understanding a characteristic of an artwork involves increasing its clearness. In recent times, the notion of 'art' has shown a particular tendency. That is, 'art expresses the human thought'. Then, the most important feature of art is that it represents the authors's view of the world. The most important feature of art is considered to be one that represents the artist's awareness for recognizing the world. In contemporary art, abstract art is divided into 'abstract expressionism' and 'hard edge'. These two types of abstract art are called as 'hot' and 'cold' abstract expressions. In modern society, these types of abstract arts reflect the typical views of artists to the world. Corresponding with art movements, emotional and simplified designs have been the two main types of designs. In both design and art, abstraction is a motif used to enact creative imagination.

At this point, we find the distinguishing features of 'the design' via abstraction. As mentioned above, there are no differences between art and design on the basis of the view that 'nothing emerges from zero'. However, the driving forces of both art and design are in opposite directions. Normally, artists evoke their imagination from any image−even from a stain on a wall− through their own memories. Their pictorial expressions are always related to any ad hoc vision. Art usually is related to its history because the intention of art is to provide the orientation for searching its origins. A stage of art is usually in the present 'is' stage and is formulated by looking back at the 'was' stage in the past (Fig. 4).

In contrast, design does not orient to the past. Figure 5 shows where the mainstay of a design is. To identify the creativity in a design, the issue of the origin of the design idea has been discussed on the basis of the knowledge of studying design cognition by focusing on concept synthesizing process in design [39]. The abstraction process in design to create a new idea, which is the ideal one, is driven by the forethought of a promise or by foresight. We propose a peculiar feature of design, namely, 'a design has a definite source in the future'.

3.3. Idealization of Design Schema

We have classified the ability of abstraction in design into two types, namely, 'abstraction in essence' (human-driven abstraction) and 'abstraction in simplified representation' (generalization). The former implies a strong motif of designing, and its process aims at achieving real abstraction. 'Abstraction in essence' involves the entireness. The latter one implies our usual rational activities. Most designed objects were produced based on the latter abstraction, which comprised some external goals but without any internal drive or criteria. If we conduct a study on designs formulated using the latter abstraction, we would never be able to capture the real abstraction and ideal design.

To identify the typical human-driven abstractions in design, we have surveyed examples presented in discussions in design studies. Coyne et al. perceived design as the situated problems in order to scope it on the basis of connection model, and they estimated the design schema in the case of house building [40]. Every design scheme is structurally based on a concrete problem. For example, a design scheme for a house can be constructed with many rooms, such as living room, bedroom, bathroom, and kitchen. In other words, a house can be represented as a composition of these rooms. They suggested that the design schema could be found in the situated functions and used to form the structures of these rooms. Their proposed example is limited in the case of physical constructions such as buildings. To develop the idea

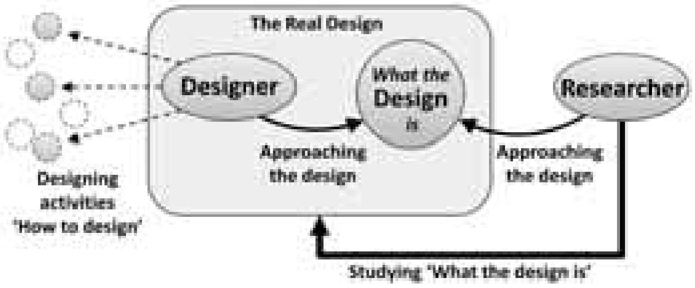

Fig.6. Study approaches to the ideal design

of a design schema, we consider that the schema should be free from the functional limitation of existing objects. The design schema should represent an ideal meaning of a house for a self. This can be accrued by a human-driven abstraction process for a house.

Moreover, to formulate a design space that corresponds with an ideal design schema, it is necessary to explore the meaning of a new relationship between the self and the objects [41]. Therefore, identifying an abstract image is needed for formulating the ideal design in an ideal situation. We have situated the real design by enlarging Visser's view [27] for studying what the real 'ideal design' is.

4. The 'ideal design'−as a conclusion

In order to identify the concept of a 'design', we first examined the motivations of design focusing on the internal perspective. We further discussed the abstraction process, which appears to stimulate creative design, especially from the perspective of the internal criteria. The internal criteria are considered to arise during a self conscious process in a commitment with the world via intrinsic motivation (namely 'drive') while having an inner perspective. One of the types of the abstraction process, which is human-driven abstraction, leads to designers being preoccupied with recognizing the world from an internal perspective. Abstraction is not a goal or purpose for the designers but a motif and drive for creative acts.

Second, we claimed another important feature to distinguish design creativity from art (from pictorial recognitions), that is, an ideal design. Needless to say, practice is necessary to research as well as learn any creative activity. Design, too, is not an exception. Visser claimed that to understand the nature of design, it is important to observe real design activities. Then, it can be said that a clue is covered in any kind of design act. Even if we observe a design of mannerisms, we consider that the core of the design is not provided. We consider that the factors of the process of ideal design enable a process to transcend problem solving. Forming internal criteria provides the answer for the argument presented by Visser stating 'design involves more than problem solving' and 'characterizing design as problem solving does not capture its essence!' Thus, we develop Visser's claim and state that 'to understand design, it is necessary to observe real designs', but we emphasize that we should study it 'particularly at the level of ideal design'. Studying an ideal design as a real design activity leads us to understand the indwelling features of a creative design.

Finally, we propose an exemplar for an ideal design. An ideal design is something that aroused from within us, which is supported by our ideal criteria. It involves the presence of the abstraction process in an ideal environment. Moreover, it produces what a design should be like from the perspective of 'future' and 'to be', which can be recognized only by human beings. At the beginning of this study we cited the definition of design that would make change the situation to pleasant one. Finally, we note that changing is not the aim of design but it will be only appeared as the results of ideal design. Given this, we show our potential to answer the challenging question of 'What design is'.

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Meta-cognition as a Tool for Storytelling and Questioning What Design Is

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1. Introduction

People without experiences of designing do not understand what design is. Donald Schon pointed out that this is the hardest paradox and problem in design education [1] ; even though a design teacher, commenting on a student's solution to a design exercise in a school, explains what designing is really and how it should be, the student without any experience of designing so far is unable to understand the real meaning of the teacher's words.

What I mean by "design" or "designing" here is not just limited to what is being educated in design schools, but also include human constructive activities in a broader sense, social or personal, to create things, states or events that do not exist at the moment. Doing scientific researches, producing new social systems, and planning social events are all design acts in social contexts. Personal activities such as changing the layout of one's own room at home and deliberating over coordination of clothes in a way that expresses oneself eloquently are design acts, too. An athlete's exploration about how to move his or her body parts to acquire a targeted embodied skill is also a design act. If people involved in these activities understand "design" better, the world around us, socially and personally, will get better. None of these "designing" activities, however, are exempt from the learning paradox mentioned above. The reality is that it is hard to tell people how to design and what design is ; those who are to design in each domain or context have to embark on designing without knowledge or understanding on what "design" is and should be.

What is it, then, that researches on design are able to do to cope with the learning paradox and hopefully create a future society in which more number of people than now are encouraged to "design" in social or personal contexts and consequently have better understanding of what design is.

First, let's look at what design researches have talked on what design or designing is. Literature on design sketches, such as in Schon [2], Goldschmidt [3], Suwa and Tversky [4], has discussed that finding new features and relations in what has been externalized so far, e.g. memos, sketches, or mockup models, is one essence of designing. A design theorist Lawson [5] argued that defining new design problems beyond given ones during a design process is one essence of designing. Recent theoretical discussion on design conducted by myself and colleagues [6] has explicated a general structure of "designing" as a cycle of acts of current noema, future noema and noesis ; when solutions to some design goals are provided in the world (acts of noesis), social interactions occur among the solutions, people's lives, and the surrounding situations. Those interactions often generate new social desires and new ways of seeing the world (acts of current noema), which in turn becomes a driving-force to generate new design problems and goals (acts of future noema). Theoretical researches of this sort, although having clarified characteristics of designing acts, do not yet provide insight on how to cope with the learning paradox ; a mere lecture on those characteristics to people, if they are without much experience of designing something, would not suffice to encourage them to "design" their life by themselves.

What, then, could or should we do as researchers? The present paper is to pose a challenging idea that one possible way of contribution of design researches is to provide such fascinating stories on designing acts that encourage people to embark on designing even a tiny aspect of their life. The idea is based on a premise that "what design is" is not something to be taught, but a kind of embodied expertise that people have to acquire through practices of designing in their real life. We believe that motivating people toward practices of designing is what design researches are for.

2. What are "good" stories on design?

What kind of stories on design attract people and motivate them to embark on "designing" in their real life. Typical stories are novels. What kind of novel is evaluated as "good"? First, novels should provide a new perspective of looking at the world, or draw attention to what normally would be unheeded.

Secondly, if people feel empathy to a novel about the ways in which its characters live their lives, it will be evaluated as good. It is the very second point, we conjecture, that seems to be the key in providing good stories on design.

How should or could we let people feel empathy to stories on design? First, stories should tell what kind of ups and downs were actually undergone during "designing" and how breakthroughs, if any, came to be realized. Those contents will serve as helpful directions and suggestions to newcomers of designing. Secondly, stories should be written as a subjective perspective of a person and about the very process in which he or she "designs" some aspects in his or her real life. The second factor is especially significant ; an objective observation from an outside perspective would not be able to go into the details of something like subjective ups and downs. Stories written on that observation would be hard to let people feel empathy. Stories from the subjective perspective contain many individual aspects and thus are hard to be generalized. However, what people look for in stories is not generalized principles or rules from the objective perspective, but a kind of typicality or empathy they can turn to as they embark on similar attempts by themselves. Therefore, we believe that stories possessing both factors will motivate people to embark on designing and give them directions and suggestions as they undergo designing in their life.

3. Embodied meta-cognition works to provide "good" stories on design

We believe that the methodology of meta-cognition is suitable for providing stories on design, because it is a general and powerful means to see a process from the endo-system view, i. e. internal observation, not objective observation from the outside [6]. If people meta-cognitively feel and externalize, by verbalizing and/or writing memos, what things went on between them and the surroundings and what thoughts and feelings came and went in them, it will provide good basis for stories on a design process.

Meta-cognition is, by its definition, cognition of cognition ; i.e. an act of reflecting on one's own thoughts, perception and movements. What we mean by "reflecting on" consists of two components ; (1) self-awareness of what we think, what we perceive, and how we move our body, and (2) thereby verbalization of them. What, thus, should be verbalized in meta-cognition is :

- what one thinks/thought,
- how one moves/moved body parts and operates on the surrounding environment,
- what one perceives from the environment through five senses, and
- what one senses though the proprioceptive system (as a result of moving body parts).

Since perception and body movements are usually performed without self-awareness, it is almost impossible to verbalize the four kinds of cognition perfectly. Important is, however, that one should make mental efforts to verbalize as much as one can be self-aware of and thereby externalize it as vocal tokens.

We have advocated that meta-cognitive verbalization serves as an effective tool for development of one's own embodied expertise [6, 7, 8]. Why is that? According to the basic notion in ecological psychology (e.g. [9]), detecting variables in own body and the surrounding environment and thereby finding new relations between those variables are the essence of learning of a living creature in the environment. Meta-cognition is a means to observe, from the endo-system viewpoint, the interactions occurring between one's body and the surroundings as mentioned above. One's thoughts and verbalization are part of those interactions. Therefore, meta-cognitive verbalization itself affects the very interactions that occur between one's own body and the surroundings. What does "affecting" mean here? It means that verbalization changes ways in which to think, perceive, and do things to the surroundings, as the notion of situated cognition suggests. This is why, we conjecture, meta-cognitive verbalization promotes detection of new variables and discoveries of the relations among variables. We have accumulated case studies of development of embodied expertise by employing meta-cognition in many domains, which include sports, such as bowling [6] and darts [8], and singing a song [10].

The essence of meta-cognitive activities lies in discovering relations among variables in own body and variables in the surrounding environment. This means, in other words, that what one does through meta-cognitive exploration is to "design" one's own body in a way in which the body fits the surrounding environment. What kinds of variables in one's own body and the surroundings one thinks relevant and what kind of relations one thinks both fit in is the most significant in meta-cognitive exploration. That is the determinant of whether or not one is able to successfully "design" one's body in a way that fits the surrounding. The reason why, as I wrote in the introduction, various kinds of human activities ranging from what is being taught in design schools, to scientific or social exploration, to bringing changes in personal daily settings, and to athletes' effort to acquire embodied skills fall onto "design" in a broad sense.

If many people meta-cognitively reflect on the processes of designing in their own contexts, including ups and downs and breakthroughs if any, we design researchers are able to accumulate them as inventories of stories on design.

To be noted in meta-cognitive activities is that the surrounding environment will never be the same, constantly changing. In order for one's attempt of "design" to be successful, one should aim at designing the own body in a way that always fits the changing environment flexibly. Consequently, "design" is inevitably a never-ending story.

We have theorized that meta-cognition is not just a means to externalize and record what is/was experienced in the mind and body, but also more importantly a tool for exploring unsolved problems and discovering so far unheeded relations between the body and the environment. Therefore, people, even if they recognize themselves as amateurs of design, do not have to be pressured that they will have to write "attractive and good" stories that augment the understanding of what design is in reader's minds. The amateur "designers" have only to come to better, even a little, understand what design is after having meta-cognitively reflected on their process and written a story. Readers of these stories do not start from scratch, being motivated by what is told in the previous stories and daring to embark on designing in their own contexts. Consequently, the whole society augment the understanding of what design is little by little.

4. A Story of Meta-cognitive Exploration of Embodied Skills in Sports

This section presents one story of meta-cognitive exploration of batting skills in baseball, a kind of "design" acts, by the author of this article who as a baseball player has undergone ups and downs and finally a breakthrough for the past two years.

4.1. Huge Improvement of Batting Average

Fig.1. shows how my hitting average changed over the past two years, the 2007 and 2008 seasons. The average is calculated as the moving average of latest three games. I played in 17 games in 2007 and 16 games in 2008. The hitting average in 2007 was 0.103, i.e. 4 hits out of 39 at bats, whereas it was 0.278 in 2008, i.e. 10 hits out of 36 at bats. As you see in Fig.1., the hitting average soared suddenly and remarkably after the end of July, 2008, which is proved by the hitting average for the last three months this year, 0.409, i.e. 9 hits out of 22 at bats. What happened to my body and cognition at the end of July this year? What have I thought and done actually in a custom of meta-cognitive exploration of my batting skills, and how did it lead to the remarkable improvement this summer?

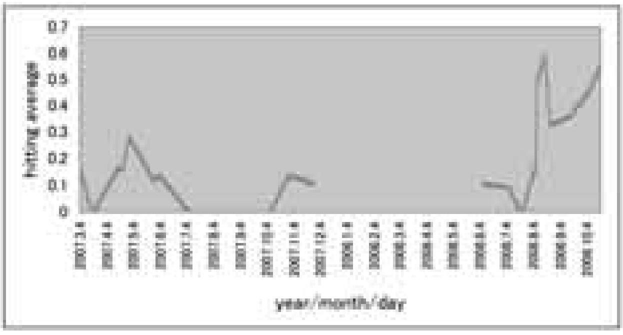

Fig.1. Hitting Average in the 2007 and 2008 seasons
(moving-average over latest 3 games)

4.2. A Custom of Meta-cognitive Exploration of Skills

I began to make it a custom to write what I did, thought and felt by reflecting on my performance meta-cognitively since summer in 2003. Since autumn in 2005 through the end of summer in 2007, I had a coach go to a batting alley together and give advice to me periodically, about once in three months. What we mean by meta-cognitive exploration does not necessarily mean that a learner is supposed to think and do exploration alone. Rather, advice by someone like a coach who has better performance and knowledge becomes significant hints for the learner's finding new variables and thinking of relations among variables, that is, boosting up meta-cognitive activities.

4.3. Meta-cognition lets us know that a drastic change is needed

Here I will write my story, beginning to talk about the 2007 season, because that was the beginning of a long lasting slump ; as you see in Fig.1., it was going to take as much as one year and a half for me to get over the slump. The 2006 season was relatively a good year to me. The average was 0.265, i.e. 9 hits out of 34 at bats, which was the highest hitting average in the team I belonged to. In spite of relative satisfaction, I thought at the end of the 2006 season that I would have to look for a better way to let the timing of my backswing fit the pitcher's motion in the 2007 season. Since I had the coach's advice periodically, I have come to do backswing slowly in a way that raises the left leg largely. This revision worked good, leading to the relative success of the 2006 season, but I have come to realize at the same time that my backswing obviously does not fit the quick motion of a few good pitchers. At the very beginning of the 2007 season the struggle for exploring for a better backswing began, which would turn out to last long, for one year and a half.

At that moment there was no proof supporting that I would have to bring a drastic change to the way of backswing. The 2006 season was a relative success, and I could have gone, then, as I did in 2006. But, what I have explored meta-cognitively throughout the 2006 season told me clearly that my body does not fit pitchers who have a quick motion to certain degree. It means, if I use scientific terminology, that my body did not fit the environment when it falls onto a specific pattern. The meta-cognitive recognition of this phenomenon is, generally speaking, a good sign that tells one that one needs a drastic change. If one begins to explore for a drastic change, it will necessarily destroy the current way of using body and lead to a slump. Although being stuck in a slump scares, one has to dare to plunge into it if one really wants to get over the phenomenon of being unable to fit body to some specific patterns of the environment.

4.4. A Period of Groping in the Dark

4.4.1. Back and forth between different thoughts

I thought that the reason the timing of my backswing does not fit to pitchers with quick motion was that I was unable to do a stable backswing. This made me begin to explore a way of stable backswing. One big characteristic of my backswing was to raise the left leg largely, taking ample time. First, for some period, I conceived of and actually tried, in the batting alley, starting backswing by raising both arms a little first, then conveying the motion through the body trunk, and finally raising the left leg, because I thought that backswing is not just a problem of legs and thus I have to use the whole body in a coordinated manner.

Then, for the subsequent period, I changed thoughts, trying to create a rhythm by both legs in a way that makes it easy to find a cue for raising the left leg. Being able to find a proper cue in one's body is highly necessary for moving the whole body easily, naturally, and in a relaxed manner.

Throughout the whole period of groping in the dark, I would repeatedly verbalize onomatopoeia to make the rhythm of my backswing fit to pitcher's motion.

After these periods my thoughts would flip back and forth among these three thoughts different from each other.

4.4.2. Approach to the core of the problem

Soon I realized from the failure in some games that merely creating a stable backswing does not suffice to solve the problem of fitting my backswing to the quick timing of some pitchers. The real problem was, I came to think, that the time I took from the beginning to the completion of backswing was too long. I thought, "Just because I use ample time for the completion of backswing, I cannot fit pitchers with quick motion." On July 12th, 2007, I wrote

> "……. Important is how I should put the whole weight on top of the right hip joint without taking much time. If I intend to put my weight on top of the right knee, I guess that it takes more time……"

But, the effort of putting the weight on top of the right hip joint quickly was going to be a failure, neither producing even a stable backswing nor creating a rhythm to make myself fit to pitchers with quick motion.

If I look backward from the current (the 2008 year) perspective, the fact that I conceived of making backswing complete in a quick manner was an approach to the essential core of the problem. But, my solution at that time, i.e. putting weight on top of the right hip joint, was not successful.

4.4.3. Bringing a drastic change in a more fundamental part

A half year went by without any success in exploring a way of making my body fit to pitchers with quick motion. That made me question if raising the left leg largely may be the fatal cause really. I have taken the large motion of the left leg for granted, so this question turned out to be the beginning of a drastic change in a more fundamental part of the body movement.

How large one raises the left leg, generally speaking, depends upon one's innate rhythm of the whole body. Changing it was a big challenge at that time. I had to look for a way of moving the whole body in which the degree of raising the left leg is reduced and the rhythm of the whole body still holds comfortable. Soon I happened to find that rotating the toe of my right foot a little reduces the flexibility of the right hip joint in the initial stance, and that the reduced flexibility not only makes me comfortable even without large raise of the left leg but also enables putting weight on top of the right hip joint quickly.

In spite of comfortableness, however, it turned out in the real game that the new backswing without large raise of the left leg could not produce a powerful swing. I came to theorize that the new backswing was to keep the source of the power only around the right hip joint, not using all the parts of the lower body, which should be far from a desirable form.

This way, the 2007 season ended with many trials and failures.

4.5. Meta-cognition serves the role of setting up an antenna for crucial variables

In January, 2008, when I had an opportunity to participate in Mr. Hiroto's workshop on how to use body in sports. He is famous for his book about a *theory* on 4 stances [11]. He theorized from the experience of practicing as a professional trainer that there are typically four types of reasonable stances. His theory amazed me in that I belong to a type, called A 1, and should make the axis of body rotation on the left side separately from the weight position during backswing (i.e. right side). At the workshop I tried to make the rotation axis on the left side of the body, i.e. around the vertical line penetrating through the left hip joint, and quickly had a proprioceptive sense that this way of backswing fits me comfortably. At the same time, I realized that all I did through the 2007 season was to make the rotation axis on the right side of my body. That was the reason why I could not shorten the time taking from the cue of backswing to its completion in a relaxed manner.

"Rotation axis" was a new variable given by him that I had never thought of. In that sense his advice about this variable helped a lot. Based on his advice, I was able to completely grasp the role of the new variable and thereby quickly theorize how I should quickly shift to the completion of backswing and adjust the rhythm of my body to any type of pitchers by keeping the state of backswing stably. At that moment I did not have to raise the left leg largely because I was able to shift quickly to the completion of backswing. All things I had explored so far were then coordinated around "rotation axis on the left side of the body". It was thanks to the meta-cognitive exploration for the past year even without any success that the whole theorization at the instant moment was made possible.

This part of the story suggests that

- meta-cognition serves the role of setting up an antenna to catch the most crucial variables,
- attention to a small number of crucial variables suffices to quickly create a theory of how the whole body should work, if the person is in the custom of meta-cognitive exploration,
- crucial variables depend on persons,
- the proprioceptive sense about the comfortableness of the whole body tells one what are crucial variables for onseself.

4.6. Meta-cognition for refined theorization around a small number of crucial variables

Making the rotation axis on the line penetrating through the left hip joint is "the" crucial variable to me. Although I was quickly able to theorize how I should move my body based on this basic principle, I still had to keep on meta-cognitive exploration to obtain a refined model of how to form backswing and then actually swing, and to find a way to actually control my body to carry it out.

Because I had a serious injury in the waist at the end of January, 2008, and had to spend three months on rehabilitation, it was at the end of April that I started playing in the game. It took three months since then for me to both complete the refined model and find a good way to carry it out in my body. It was at the end of July this year, as I mentioned in the section 4.1, that I finally got out of the long lasting slump and kept the high hitting average, more than 0.400, for the last three months of this season.

The first problem I encountered in games and during practices at the batting alley was the following; too much attention to making the rotation axis on the left side of the body, i.e. the side of the pitcher, causes stiffness of the usage of the upper body. I set up an aim of removing as much strain of muscles in the upper body as possible. Then, I encountered a book written by Michizo Noguchi [12]. My meta-cognitive antenna caught two notions in the book; one is that one has to breathe out the air in order to relax, and the other is that one has to stand by bones only without using the strain of muscles in order to relax. This quickly made me notice meta-cognitively that I had breathed in during backswing. I was going to carefully control my breath at bat so that I can clearly breathe out at the timing of backswing. As far as standing by only bones is concerned, I quickly came to realize that I should stand still at bat by focusing attention only to the pit of the stomach, which according to Mr. Hiroto's theory is the most important part for a person belonging to A 1. Since then I was going to explore a better way to remove strains of the upper body during backswing, focusing attention to two things only; one is to breathe out and the other is to start backswing by shifting the pit of the stomach right downward toward the toe of the right foot, where all the weight was put on during the backswing.

A quick completion of backswing that I kept exploring for during the 2007 season in vain is still one of the most important things to be done. Focusing attention only to the way of shifting the pit of the stomach worked well. Further, standing straight with the width of both legs being narrow and without bending knees enabled completing backswing quickly and keeping it for long in a relaxed manner to adjust to any type of pitchers.

Another important variable, I found during the period of refinement, was the movement of the left leg during backswing. As mentioned above, keeping the rotation axis on the left side of the body is a must-do principle. In order to keep it, the left leg necessarily needs to be located far left to compensate the shift of the body trunk (around the pit of the stomach) toward right. This seemed to me a logical conjecture. Since the left leg is near the right one at the initial stance, the left leg should move toward the left side as the body truck shifts right. Consequently the whole body stretches out diagonally from the right top to the left bottom.

This is the end of my story as I went through a long lasting slump, exploring a better way of backswing, and finally experienced a huge breakthrough. This is an act of “designing” my body in a way that fits the surrounding environment of any types.

5. Conclusion

Everybody who has embodied experience of designing in his or her real life understands well that “design” is an endeavor to bring a new perspective to see the world, and that “learning design mind” is to acquire it as embodied experience. However, these are to be learned only through embodied experience, i.e. embarking on a designing act by oneself. It is almost impossible to teach what design is by explaining theoretical notions or the general structure of designing. All that design researches can do is to motivate people toward designing even if they do not have sufficient knowledge about what design is.

We have argued that meta-cognition is useful in two ways in the context of design teaching. First, if design researchers and designers meta-cognitively reflect on their process, they are able to write stories from the perspective of persons as they design, i.e. internal observation from the endo-system view. Just because those stories provide an internal view of the very person who designs, it can possibly motivate amateur people toward designing and give directions as they design. This is a form of teaching what design is through story-telling, not by conceptual explanation.

Secondly, meta-cognition, due to its innate nature of internal observation that affects interactions between the body and the surrounding, serves as a tool to discover new aspects. If people including designers, researchers and even amateur designers reflect on their design processes meta-cognitively, it will necessarily augment understanding of what design is. Meta-cognition seems to be an effective methodology, too, for questioning what design is.

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Nature of Design from an Architectural Point of View

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1. Introduction

This article characterizes the constructive nature of design in terms of a model of design process, the classes of features of the things involved in design, the nature of law, polysemic dualities in design, and scientific inquiry[*1] . Some examples are given from a point of view of architectural design.

Whatever an activity of design would be, a certain thing is produced in an environment as the result of the activity and a certain phenomenon is promoted as the consequence of the interaction between the product and other things in the environment. The user of the product is one of the other things. We call a thing that is produced with the purpose of promoting something as an artifact. An artifact doesn't exist without the activity of generating it. An artifact is generated by making or performing a thing as well as by giving significance to the thing. One of the essential significances is to change existing situations into preferred ones [1]. By definition, an artifact cannot be independent from such kind of significance. However, the made or performed thing is not necessarily new one. An existing thing could be a new artifact if certain significance is given to the thing. For instance, a cave became a house, which is the artifact providing a place for living, when our ancestors settled there even though it has been naturally made and already existed before the settlement. Our ancestors practically generated a house by living in a cave. They gave meaning as a place for living to the cave by actually living there.

2. A Model of Design

The notion of design refers to an activity of forming a new schema coupling things and its assigned significances as well as of embodying the schema in a certain artifact, concurrently. A schema describes the constitution of an artifact, the mechanism how the artifact brings about certain situations, and the course of events where the artifact is embodied. Beliefs about the nature of law related to the things are employed to determine the features of the schema and those of the artifact. The immediate products of design are a new schema and an artifact as an instance of the schema. The indirect products of design are the expected phenomena as instances of the given significance and the unpredicted phenomena as secondary effects. The secondary effects could be either favorable or not. If the effects are favorable then they may be expected explicitly in the succeeding design. If not, the schema and the artifact are improved so as not to bring about such phenomena.

An image of design is depicted in Fig.1. Design is the combination of generation and analysis. The two processes are performed sequentially or synchronized with each other. In generation, a scheme of the artifact that is expected to have the potentiality to change the current situation into preferred one is formed. Generation produces a course of actions to embody the artifact, too. In analysis, it is predicted what if the artifact is embodied and implemented in a particular environment to let the artifact interact with the environment. The beliefs about the nature of law are used as grounds for the prediction. If it is convinced that the artifact has the expected potentiality based on the consequence of prediction then design finishes. A course of action to change the current situation into preferred one is determined. If not, the schema of the artifact and some beliefs are modified to fill the gap between the preferred situation and the predicted situation. The figure emphasizes that the products of design are not only an artifact but also some phenomena brought about by using the artifact.

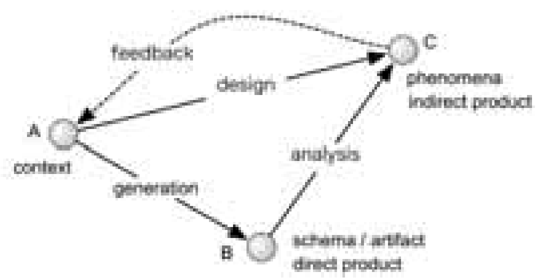

Fig.1. An Image of Design

Design is constructive. The crucial nature of design is that a new schema has to be formed on the basis of the current

[*1] Hideyuki Nakashima discusses constructive design process in this special issue.

beliefs and hypotheses about the nature of law. The beliefs and hypotheses are constructed without the new schema. They will probably be modified when the interactions between an artifact with the schema and its environment are analyzed. If the schema is not consistent with the modified beliefs, the schema loses some of the grounds. It is hard to consider all of important aspects prior to generation. Some aspects that have not been noticed are found to be important through the interaction. Therefore, the concurrent cycle of generation and analysis is repeated until design is almost completed. This means that design is constructive and has dialectic nature.

3. Features of Design Objects

We assume that a thing is differentiated from the other things by its features. The features of a thing define the characteristics of the thing. A thing is identical to the thing whose features are entirely the same. A thing and another thing are different from each other if some features of the former differ from some features of the latter. On this assumption, a process of design is formulated as a process of making the features explicit.

The features are classified as proximal features or distal features depending on the level of the granularity, scale, and abstraction adopted for the observation of the thing that has the features. The classification is relative since the level for the observation changes. A proximal feature is the feature that articulates a distal feature. A distal feature is the feature that emerges as an appearance of the unified totality of proximal features. The proximal features are recognized as the constituents of the distal feature, but the distal feature cannot be explained completely in terms of the proximal features. For example, the comfortableness of an architectural space could be a distal feature whose proximal features are the thermal comfort of the space, the safety from fire, earthquakes, and intruders, the usability, the beauty, and so on. The thermal comfort of a space could also be a distal feature whose proximal features are the temperature, the humidity, the wind velocity, the metabolic ratio of the occupant, and so on.

The features are also classified accessible features, controllable features, inaccessible features, or emergent features depending on the level of accessibility to the features. We assume that a feature can be directly determined or controlled in design if it is perceived as a proximal feature. A feature can be determined directly in the sense that it can be specified whether a schema, an artifact, or a phenomenon in question has the feature or not. We call such a feature as an accessible feature, or A-feature in short. A feature can be controlled in the sense that it is possible to specify the feature indirectly but conclusively by determining other features. We call such a feature as a deducible feature, or D-feature. It is presupposed that an A-feature and a D-feature have a causal relation that an A-feature is the cause of a D-feature. For example, the material, the shape, and the dimension of a wall of a building are A-features since they can be directly determined. The heat conductance and the heat capacity of the wall are D-features since they are conclusively specified if the material, the shape, and the dimension of the wall are determined. An inaccessible feature, or I-feature in short, is a feature that cannot be determined, controlled, or affected. An emergent feature, or E-feature in short, is the feature that emerges as an appearance of the unified totality of A-features, D-features, and I-features. Those features can give influence on the E-feature. The thermal comfort of a space can be affected by controlling the temperature by determining the structure of the walls of the space. An E-feature, here, is a distal feature whose proximal features are the A-features, D-features, and I-features. As it is relative to observation whether a feature is proximal or distal, a feature seen as an E-feature in an observation can be seen as an A-feature, D-feature, or I-feature in another observation.

Two types of classifications construct a hierarchical structure of the duality of proximal features, i.e., A-features and D-features, and distal features, i.e., E-features. Fig.2. depicts the hierarchical structure.

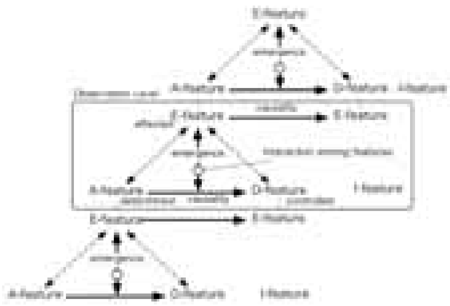

Fig.2. Hierarchical Structure of Features

It is often the case that the significance of a thing being designed is described in terms of E-features promoted by the thing. In design, A-features are determined directly and D-features are controlled under the constraints described by I-features in the expectation that the E-features emerge upon the interaction among the features. An artifact is specified in terms of A and D-features. The significance of the artifact is described in term of E-features. The schema embodied by the artifact is described as the relation among A, D, I, and E-features. Design explores the specific features towards the preferred situation as well as the relation among the features. A process of generation in design is formulated as a process where relations among features are assumed and A-features are determined with respect to the relations. A process of analysis is formulated as a process where D-features are deduced from the A-features and it is predicted, on the basis of the relations assumed in generation, whether the expected E-features emerge upon the interaction among the A-features, the D-features, and the I-features or not. The assumption about the relations is modified to fill the gap between the prediction and the expectation in the succeeding generation process.

4. The Nature of Law for Design

A process of forming a schema and embodying it as an artifact is not an arbitrarily or randomly performed activity. All of A-features are not determined arbitrarily or randomly. Some A-features are determined on certain grounds. The relations among the features derived from the nature of law are consciously applied to form a schema with the conjecture that an artifact with the schema facilitates the expected features. It is essential for the success of schema forming to refer the nature of law that governs the features. It is preferable but not necessary to know what exactly the content of the nature of law is [2]. It is important to do something with he consciousness of existence of the nature of law. The nature of law could be subjective, or private, in the sense that it represents personal understandings of the world formed through the experience. It is not necessary that the nature of law is objective or public in the sense that it is verified in a so-called scientific manner, either. Even though it is subjective or private, it plays an important role to define the direction of design. To form a schema is to construct the hypothetical relations among the features. The hypothetical relations should be consistent with the relations among the features that are governed by the nature of law. We assume that the objective type of the nature of law navigates the designer towards a rational direction and that the subjective type of the nature of law navigates the designer towards a creative direction.

The nature of law is expressed in some ways. (A) Some laws are expressed in the form of an equilibrium governing A-features, D-features, and I-features. The features must be in the same proximal level. A distal feature is not expressed in the equilibrium since a distal feature is defined as the feature that cannot be described by its proximal features completely. Formal and scientific knowledge is expressed in this form. Heat balance and dynamic system are expressed as equilibriums. (B) Some laws are expressed as qualitative or quantitative causalities between two things. A thing is expressed as the cause of the other thing, or a thing is expressed as the effect of the other thing. Procedural knowledge, which couples means and ends and is applied to plan a course of actions in generation, is expressed in this form. The relations between the emergent behavior of a system and the behavior of the constituents of the system are also expressed in this form. At least one of the two things can be an action. When an action is the cause of the other thing, the thing is the result or consequence of the action. When an action is the effect of the other thing, the thing facilitates the action. Proximal features as well as distal features can characterize the things involved in this form of expression. Therefore, vertical causality [3], which bridges different conceptual levels, is expressed in this form. The notion of vertical causality refers to the causality among the features in the different conceptual level. The relations among the proximal features controlled directly and the distal features brought about as the consequence of the control are expressed. (C) The rest of the nature of law is tacit and not expressed explicitly in the forms described above. It could be expressed implicitly in a narrative form. Intuitive beliefs about the nature of law, which determine which features should be focused in design, cannot be expressed in the form of either equilibrium or causality. The focused features are important to determine the direction of generation and analysis.

5. Polysemic Dualities

The discussion above suggests that there are polysemic dualities in design. Design aims at producing a schema and an artifact as well as promoting a certain phenomena as the significance of the artifact. The significance is evaluated from a practical point of view concerning whether existing situations can be changed into preferred ones as well as from a theoretical point of view concerning how the relations between the artifact and the phenomena are understood on the basis of the nature of law. Design applies the nature of law for generation and analysis as well as constructs the nature of law in generation and analysis. The schema associating an artifact with the significance is formed with respect to the nature of law as well as the nature of law is modified constructively to understand the consequences of forming the schema. The proximal features as well as the distal features describe the things involved in design. It depends on the conceptual level of observation if a feature is proximal or distal. The dualities of the proximal and the distal features organize the hierarchical structure corresponding to the levels of observation. Design produces an individual schema as well as a general schema.

A schema defines the composition of an artifact, from which artifacts in the same class are embodied, and formulates the mechanism underlies emergence of the expected situations upon the interaction between the artifact and the environment. A schema is individual in the sense that it is formed so as to fulfill particular expectations in a certain context. A schema is general in the sense that it is possible to apply the schema to different contexts so as to produce similar individuals that fit the contexts. The individuality and the generality are mutually necessary even though they vary in accordance with interests in design on which the emphasis falls. A general schema is an abstraction of the interested features from an individual schema. The significant features of interest are selected for the abstraction. The general schema should be transmitted to instantiate other individual schemata. Adding some features to the general schema in accordance with the context where the individual is being formed forms an individual schema.

6. Design as Scientific Inquiry

We model a process of design in terms of the forms of inferences, i.e., deduction, induction, and abduction. Peirce [4] modeled a process of scientific inquiry as cycles of abduction, deduction, and induction. We will see that the model of a design process is similar to that of scientific inquiry if we focus on the forms of inferences employed in scientific inquiry and design .

(Step-0) Every design is motivated by the consciousness of one's will to produce an artifact so as to promote preferred situation. An exploration into the schema that realizes the will begins. (Step-1) The designer imagines, based on the past and present experiences, how the situations will change if a certain schema is embodied. The designer invents some hypotheses that shall fulfills the will, and selects the one that seems promising. A schema that is consistent with the hypothesis is formed. There is no logical way to invent or select the most plausible hypothesis and to design the consistent artifact. (Step-2) The designer predicts the conditional experiential consequences that would be logically or probably derived in accordance with certain inference rules if the selected hypothesis were true and the schema were embodied. (Step-3) The designer actually embodies the schema and verifies how far the predicted consequences are consistent with the experiential observations as estimating the proportion of truth of the hypothesis and judges whether the schema and the hypothesis are sensibly correct, or require some inessential modification to fulfills the intention, or must be rejected. (Step-R) Step-1, 2, and 3 are repeated until the designer forms the schema that enables the preferred situation.

Either abduction or induction doesn't have logical inference rule that guarantees the truth of the consequences in spite that deduction does. Therefore, the success of design as well as scientific inquiry depends not only on the procedural schema like the rules of deductive reasoning but also on the heuristic capacities to be employed to select the most plausible hypothesis, to classify the empirical observations, and to imagine a course of action towards the goal.

7. Summary

We characterized the constructive nature of design in terms of a model of design process, the classes of features of the things involved in design, the nature of law, polysemic dualities in design, and scientific inquiry.

Acknowledgment

Discussions given in this article are mostly the result of an on-going and long discussion with Hideyuki Nakashima (Future University – Hakodate) and Masaki Suwa (Keio University), and partially inspired by discussions with Yoshitsugu Aoki (Tokyo Institute of Technology).

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Design of Worth for Consumer Product Development

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Abstract

Worth is assessed throughout the Life Cycle. Then we consider a trade-off between Worth, Cost, and Time. This methodology is a concerning selection of design solutions from thousands of combinations of design parameters. The current Design for X (DfX) is considered to be extended, and so the methodology is called Extended DfX. Here, this methodology is applied to consumer product development. Worth of consumer products is especially important, but Worth is not always equivalent to performances, whereas it usually is in the case of other products. Therefore, a novel approach is required for assessing Worth in consumer product development. The design for product sound quality is also introduced as the another approach for the design of worth.

Keywords

DfX ; worth ; cost ; time ; customer ; function ; structure ; PC ; trade-off ; method ; tool ; optimization ; Sound ; Sound quality ; SQ metrics ; Noise ; Multiple classification analysis ; Psychoacoustic

1. Introduction

The process of product development varies greatly depending on the product field. Fig.1. shows an example of classification of the product development pattern. The axis of abscissas indicates the size of the product development in proportion to the development cost. The vertical axis indicates whether the objective is mass production for an unspecified client or production ordered by a specific client. Power plant and space equipment correspond to the lower right region. This region is a product field in which development cost is high and the performance can be investigated thoroughly over a long period of time. The consumer product that is the target of this paper is antithetical to power plant and space equipment. This region is a product field in which investment in product development is relatively small and development time is short. The product of this region is customer-driven. Fig.2. shows various methods/tools for the product development [1, 2]. These methods/tools can be extensively used for the above-mentioned plant and space equipment. On the other hand, it is necessary to apply them selectively and efficiently in the case of consumer product development.

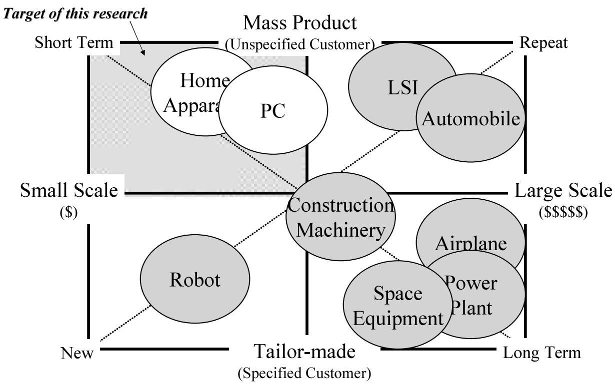

Fig.1. Product classification

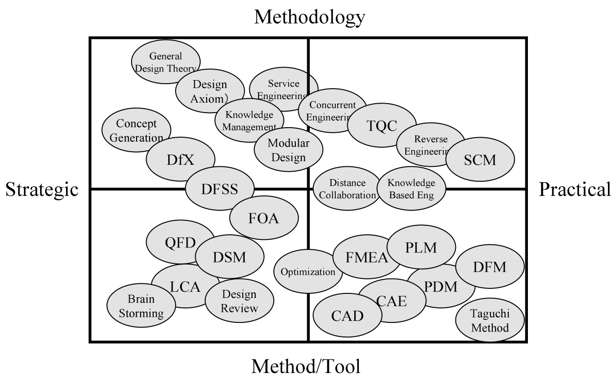

Fig.2. Design Method/Tool

In this paper, we propose a design concept for consumer product development. In the case of consumer product development, a customer has the ability to decide the product price in many cases. This causes a manufacturer to make a product that has less variety. As a result, a manufacture endeavors to reduce costs by improving efficiency and becomes caught up in price-driven competition. In order to break this cycle, it is necessary to assess Worth from the manufacturer's point of view and to reflect the result in product development. Many studies have attempted to evaluate worth/value from the customer's point of view [3, 4]. That is, a potential customer requirement is analyzed, and quantified as absolute worth (we define this as Worth) independent of cost. Then, we estimate Cost to realize the above-mentioned Worth by using Worth/Function/Structure relation graph [5]. We define this concept as Extended DfX methodology, an extension of the current DfX [6] to Worth-based product development.

The design for product sound quality is also introduced as the another approach for the design of worth. This methodology incorporates two evaluation methods. One is a sensory evaluation method employing the semantic differential (SD) technique, which determines psychological metrics to measure the level of pleasant sound. The other is a physical evaluation method to which Zwicker's sound quality metrics analysis can be applied, which determines physical metrics to measure the level of pleasant sound.

2. Trade-off between worth and cost

Here, for the sake of simplicity, we consider a product composed of three kinds of parts : a, b, and c. Each of these parts has two kinds of grades : 1 and 2. Then, eight kinds of products can be considered in accordance with the cube of two as shown in Tab.1. Roughly speaking, the cost is defined as the sum of the cost of each part for eight kinds of products. On the other hand, Worth at the component level increases if the grade is higher. However, unlike in the case of a CPU, Worth is not always proportional to price. There are some nonlinear factors. In addition, product Worth itself is not equal to the sum of component Worth. Harmonious balance as the product greatly affects Worth. In addition, Worth strongly depends on the user of the product, when it is used, and where it is used.

We assume that Worth of each of the eight kinds of products is obtained by some means. The result is plotted on the Worth/Cost map as shown in Fig.3. If the relation between Cost and Worth is linear, eight kinds of points are plotted on the straight line. However, since Worth is defined through a rather complex process, results will be scattered as shown in Fig.3. An actual product consists of dozens of parts and grades. Moreover, the style, the color, weight, size, etc. should be considered for evaluation of the relation between Cost and Worth. Therefore, thousands of product varieties exist. Once Cost and Worth for thousands of product varieties are plotted on the Worth/Cost map, a group of product varieties can be visualized. Then, the boundary of the lowest Cost limit and the highest Worth limit come into view. This boundary is called a Pareto optimal solution. Products B and F in Fig.3. correspond to this solution. That is, we can see a group of best solutions by mapping Cost and Worth on the Worth/Cost map like this. This is why we focus on Worth and compare Worth and Cost on an equal footing.

We consider a trade-off between Worth and Cost, but we may include Time (schedule) in addition to Worth and Cost. Product B and product F are optimal solutions in the current state. The optimal solution does not always satisfy the target solution. In this case, the reduction of Cost down and the increase of Worth will be needed in order to approach the target.

Tab.1. Product Varieties

Product	A	B	C	D	E	F	G	H
Part a	a1	a1	a1	a1	a2	a2	a2	a2
Part b	b1	b1	b2	b2	b1	b1	b2	b2
Part c	c1	c2	c1	c2	c1	c2	c1	c2
Worth	x1	x2	x3	x4	x5	x6	x7	x8
Cost	y1	y2	y3	y4	y5	y6	y7	y8

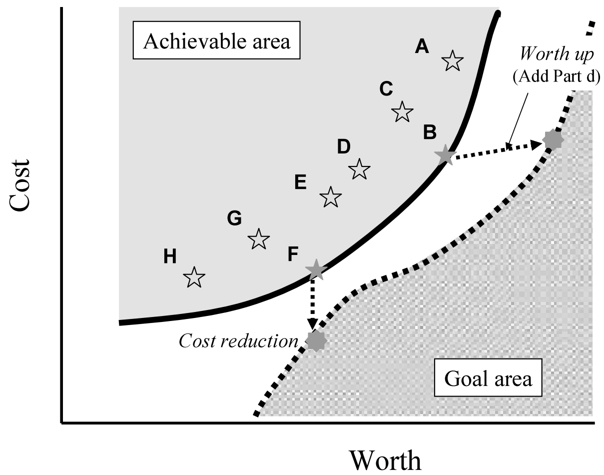

Fig.3. Worth/Cost Map for Eight Products

3. Extended DFX methodology

We propose Extended DfX methodology that enhances the DfX design procedure for digital consumer product development. DfX is a philosophy and practice advocated by Gatenby of Bell Laboratories, of AT&T, in 1990 [6] that ensure quality products and services, reduce the time to market for a product, and minimize life-cycle costs. That is, it is a way of evaluating various problems throughout the life cycle at an early stage of product development as much as possible, and decreasing the redesign in the latter half of the product development as much as possible. In practice, the design method/tool shown in Fig.2. is systematically applied according to the DfX methodology. It is comparatively easy to apply the DfX methodology to large-scale product development, but for consumer products a more concrete way of focusing on Worth is required. So, the DfX methodology is expanded to include the design of Worth as shown in Fig.4. Worth is set first, and Cost is derived through functional design and structural design. Worth becomes the target for the customer and Cost becomes the target for the manufacturer, that is, this is a trade-off between Worth and Cost.

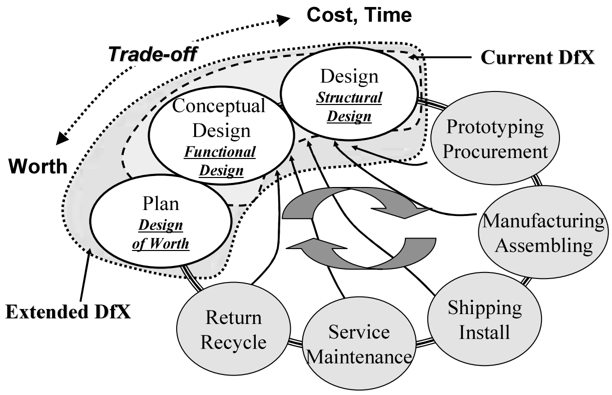

Fig.4. Concept of Extended DfX Methodology

In general, the relation between Worth and Cost is mapped on the Worth/Cost graph as shown in Fig.5. An achievable area is obtained by trade-off analysis, but generally neither an achievable area nor a goal area corresponds. This is a kind of trade-off. A trade-off analysis method that uses GA has recently been established and can be applied. Thus, the problem becomes clear by plotting current design on the Worth/Cost graph. For instance, the cooling method becomes a problem when the generated heat grows by advancing CPU performance as shown in Fig.6. in notebook PC design. If we introduce a large fan system to remove the generated heat from notebook PC with high-performance CPU, the entire PC becomes large, and Worth for customer decreases overall. Therefore, a technical breakthrough for heat rejection is required.

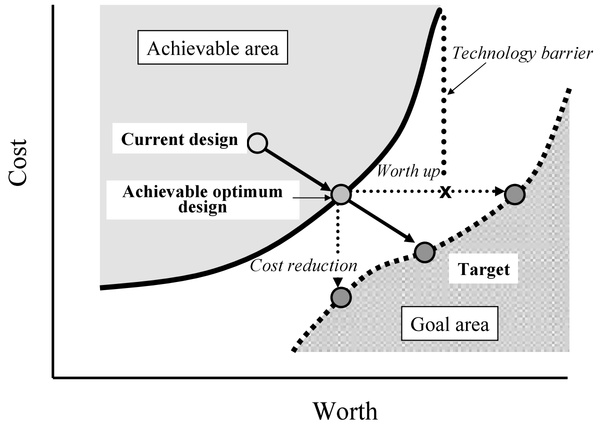

Fig.5. Worth/Cost Map

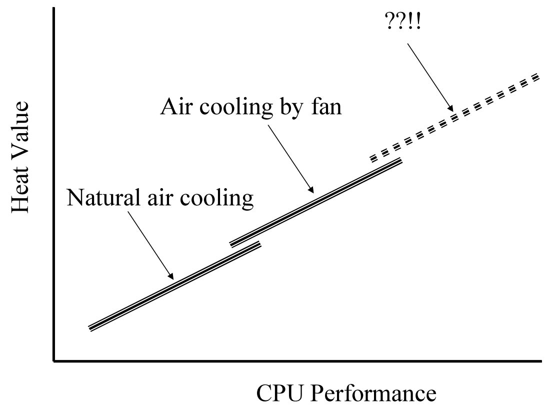

Fig.6. Need for Break-through Technology

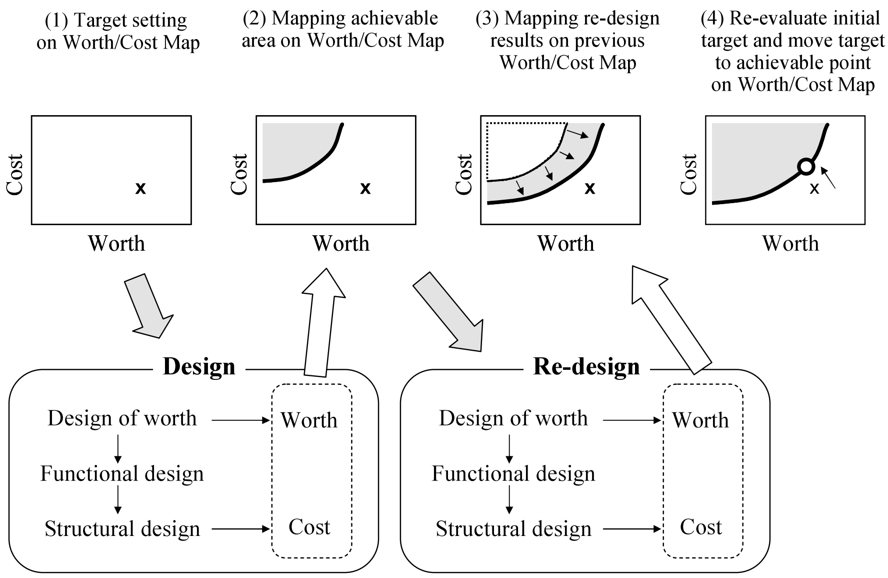

Fig.7. Procedure of Extended DfX

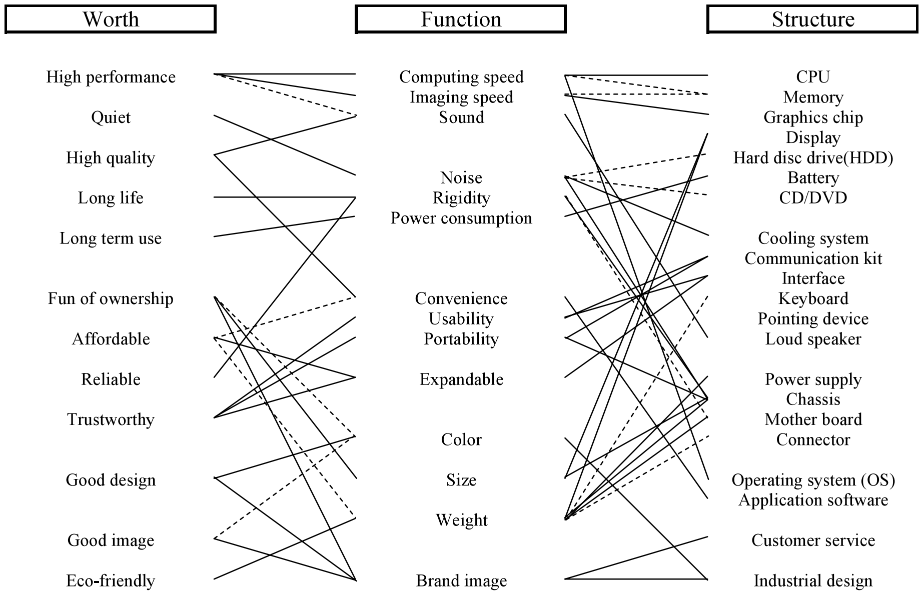

Fig.8. Worth/Function/Structure Relation

We explain the procedure of the extended DfX by referring to Fig.7. First of all, the target is set on the Worth/Cost map. This is at the planning stage. For example, PC with Worth equivalent to $4000 is developed at a Cost of $2000 for the power PC user. Next, “Design of Worth”, “Functional design”, and “Structural design” are executed in accordance with the DfX methodology. Worth is obtained from “Design of Worth”, Cost is assessed from “Design of the structure”, and, as a result, Worth and Cost are plotted on the Worth/Cost map. In general, because the design achievable area doesn’t satisfy the target at this stage, we need to redesign to obtain new Worth and Cost close to the target by controlling design parameters and design restrictions. New Worth and Cost are plotted on the Worth/Cost map again. This procedure enables us to approach the target. An initial target is re-evaluated when we judge that the achievement of an initial target is difficult, and the agreement point of the design feasible region and the design target is set. In practice, this design process is executed by using the Worth/Function/Structure relation graph shown in Fig.8.

4. Design for product sound quality

All the sounds generated by an operating product have been considered to be noise so far. Therefore, both users and manufacturers have tended to view a product with a lower noise level as a better product. However, sound is a key factor in Kansei/emotional information, whereas noise reduction is subject to a limitation. The product sound should not be considered as a negative direction of noise but treated as one sound. Product worth can be enhanced by improving the product sound. That is, the targeted product sound is appropriate or not for the customer, if not, how to realize the appropriate product sound. This approach is important because it enables the manufacturer to add worth to the product.

The performance and the sound (noise) of the product are closely related in the case of home appliances. For example, “collecting garbage” and “sound” cannot be considered separately in the case of a vacuum cleaner. In product sound design, noise reduction techniques have been executed mainly from the viewpoint of “noise”. Moreover, noise reduction techniques have been applied to products that are already completed to some degree.

Fig.9. shows the design methodology for product sound by comparing the “as-is” and the “to-be” product sound definition. In the traditional approach to noise reduction, product sound is treated as noise that should be minimized as much as possible. Moreover, because performance is the first priority and noise reduction is a secondary issue, countermeasures to reduce noise are usually implemented after prototyping. Thus, the product worth generated is determined by the decrease of a negative impression.

On the other hand, in the design for product sound quality, the product sound is treated as sound that adds worth to the product. Therefore, the customer’s preference in terms of sound is defined and a strategy to realize this is required. The worth realized by this approach can endow the product with an attribute that gives a positive impression to the user. However, for this purpose, it is necessary to embrace the view that "the product sound is not a noise" and the metrics for designing the sound at the product design stage should be defined.

The conventional product development process is shown in Fig.10. The new idea for the next product is decided by analyzing the sensory evaluation and the evaluation of sound quality metrics. In this case, the sensory evaluation and the evaluation of sound quality metrics are performed separately. For the next product embodying the new idea, the sound evaluation can be performed after prototyping. When the sound after prototyping is unsatisfactory, countermeasures should be implemented within the time and cost constraints.

On the other hand, the design for product sound quality determines the metrics for product sound, considering both the sensory evaluation and the evaluation of sound quality metrics. The target sound for the next product is determined according to the metrics for product sound. As the target sound is defined physically, this can be produced virtually by a digital sound tool. Therefore, the sound evaluation for the next product can be performed before prototyping. Next, the product sound design is performed to realize the target sound, considering performance etc. Finally, a product with excellent performance and sound can be realized.

Fig.11. shows the procedure of the design for product sound quality. It is necessary to define two metrics to perform the product sound design. First, an impression evaluation is performed by sensory analysis to evaluate the customer's impression of the targeted product sound. In the impression evaluation, target customers listen to the targeted sound. Then,

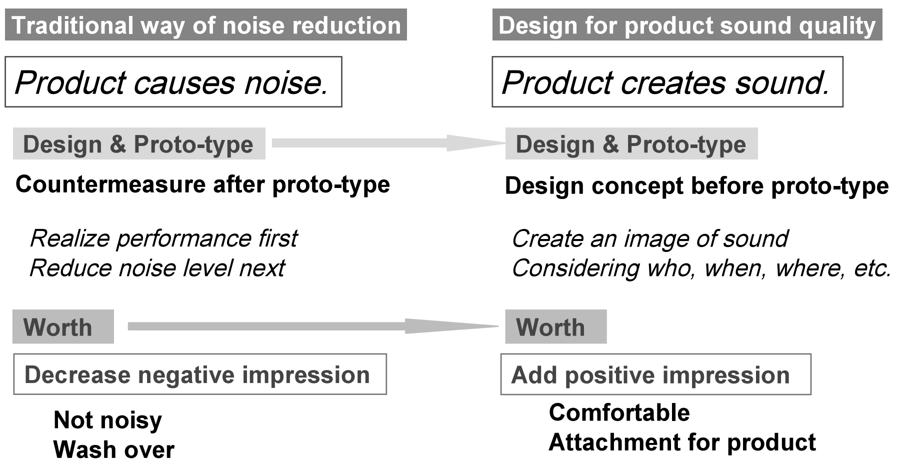

Fig.9. Design methodology for product sound

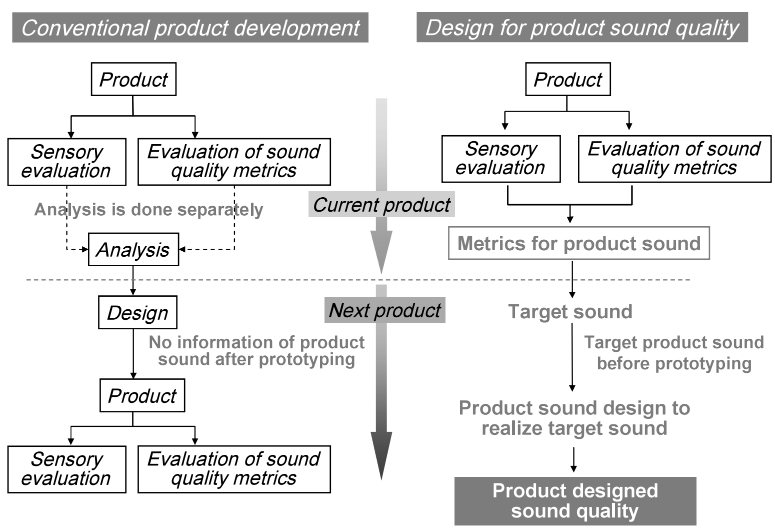

Fig.10. Design for product sound quality

the VoC (Voice of Customer) revealing potential needs concerning the sound is analyzed by the SD (semantic differential) method and/or the method of paired comparison, etc. The results are transformed into the metrics for product sound by multiple classification analysis. The metrics obtained by the impression evaluation is defined as the psychological metrics here.

The psychological metrics is important for quantifying how the customer's impression of the targeted sound. However, it is difficult to combine the targeted sound with the sound design only on the basis of the psychological metrics. It is also necessary to express the targeted sound physically by means of an objective evaluation. As measurable design parameters of the product sound, we use four basic SQ (Sound Quality) metrics [7] : loudness, sharpness, roughness, and fluctuation strength. These are widely used and well defined.

These basic metrics are not always defined physically but derived through many sensory evaluations. These SQ metrics can be applied directly to the objective evaluation, but as the number of SQ metrics is rather big, it is necessary to define a new metrics using these SQ metrics. Moreover, it is notable that some product sounds cannot be defined by these SQ metrics. In this case, we should define the new metrics for the principle of the physical meaning. The metrics obtained by the physical evaluation is defined as the physical metrics here.

Generally, the psychological metrics is used for sound design. However, because the target sound is not expressed numerically (physical metrics), it is difficult to design product sound directly from the psychological metrics. So, the psychological metrics should be reflected in the design of product sound through the physical metrics. For this purpose, the relation between the psychological metrics and the physical metrics should be defined. This relation is the metrics for product sound. After defining the metrics for product sound, the target product sound is set. The target sound set in the psychological domain is mapped into the physical domain. The target sound mapped in the physical domain is not unique. Finally, the target sound is determined, considering the easiness of realization etc. This target sound becomes a specification of the design for product sound quality that achieves the worthy sound.

5. Application of design for product sound quality

The application of the design for product sound quality to a vacuum cleaner is introduced. A vacuum cleaner makes a continuous sound during operation. The product sound is classified into continuous sounds, discontinuous sounds, unexpected sounds, etc. Continuous sounds are common and fundamental to the product sound. In the case of vacuum cleaner sound design, we would pursue "sounds like vacuum cleaner", "feeling of luxury", and "sounds heard softly". Our target for vacuum cleaner sound is the inclusion of these ambiguous requirements in the product development. This paper presents the first step toward realizing that target.

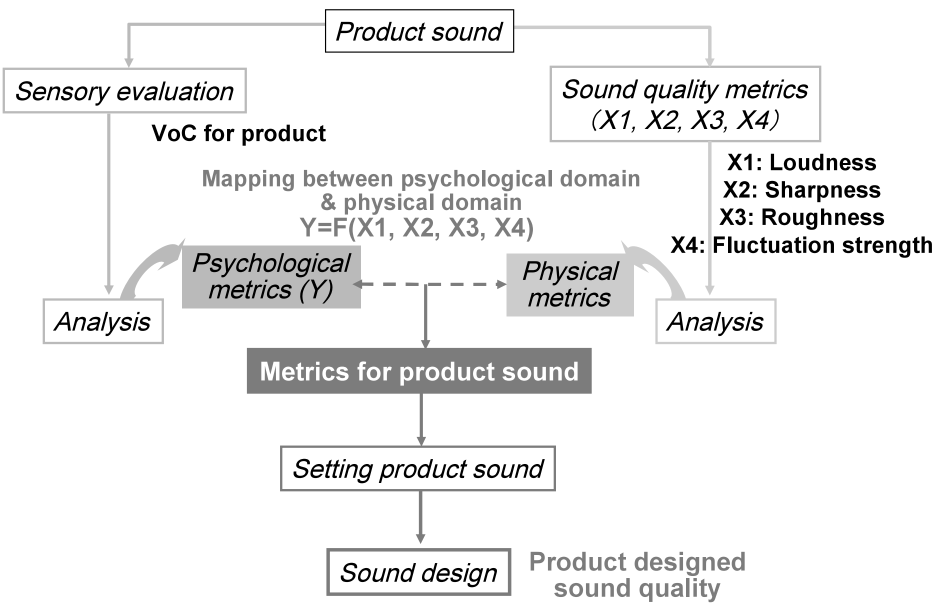

Fig.11. Procedure of design for product sound quality

Here, the sensory evaluation, the physical evaluation, and the mapping between sensory evaluation and sound quality metrics are performed for the sounds of 10 models.

Fig.12. shows the application of the design for product sound quality to a vacuum cleaner. The design process is divided into two parts : "sensory evaluation" and "physical evaluation". The stationary sounds from 10 selected models of different manufacturers are recorded in an anechoic chamber and used as evaluation samples.

In the sensory evaluation, 22 examinees listen to the sounds of the 10 models. The SD (semantic differential) method is applied to responses consisting of 25 pairs of adjectives (16 pairs of general adjectives and 9 pairs of product-specific adjectives). When the SD method is applied to the sensory evaluation, it is important to select a pair of adjectives carefully. First, the target was clarified and then a pair of adjectives to be extracted is selected.

The 22 examinees are divided into four groups and seated in front of a speaker. Each sound is played for five seconds and the examinees give their impressions of the sound by completing a questionnaire consisting of adjective pairs. Two trials of the same experiment are conducted to test the reliability of the data. To avoid the influence of the learning curve, the examinees practice responding before the experiment is performed.

The multiple classification analysis is applied to the value of 25 pairs of adjectives (mean value of 22 examinees) for the sounds from 10 models. As a result, the principal components shown on the left in Fig.12. are obtained. Here, the primary principal component is defined as the psychological metrics. Fig.13. shows the relation between the physical and psychological metrics based on Fig.12. We call this relation "sound measure for vacuum cleaner". This figure means that the smaller the psychological metrics, the better the sound quality by the sensory evaluation of 22 examinees. The physical metrics for the sounds from 10 models are widely scattered. The sounds that exist in the vicinity on this figure have similar sound quality. The physical metrics is related directly to the sound design.

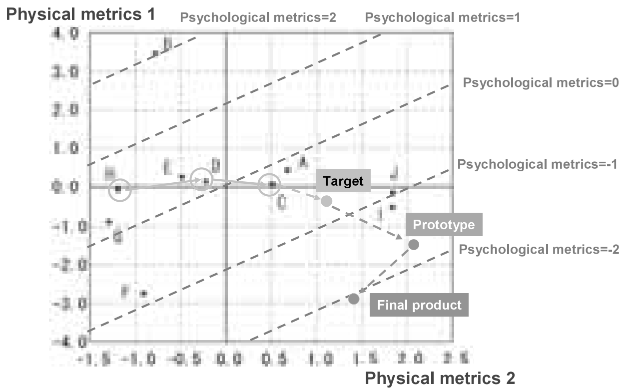

Fig.13. Relation between physical & psychological metrics for setting of target sound & final product sound

Next, the target sound is set in terms of the physical metrics. Fig.13. also shows the procedure of the target sound setting. Models H, D, and C are by the same manufacturer and the design has been improved in this order. The conventional product development results in the improvement of the product sound. The target sound is set based on the current model C as

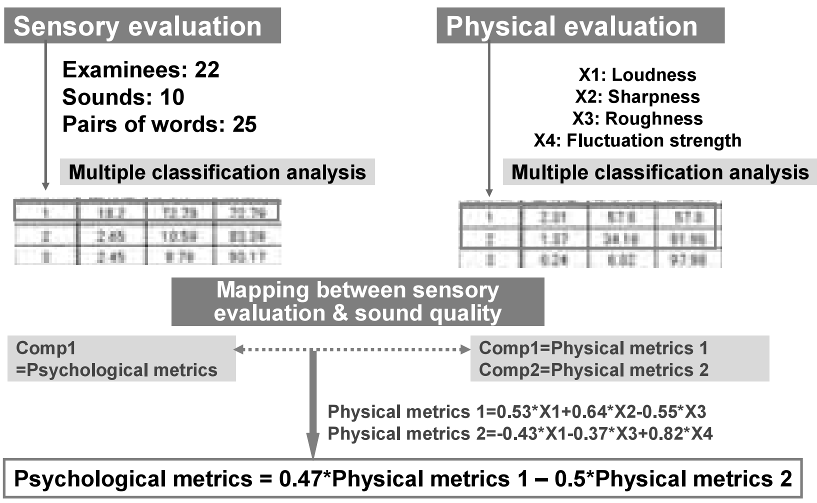

Fig.12. Application of design for product sound quality to vacuum cleaner

shown in Fig.13. This figure also shows the results for the prototype and the final product. The sound for the prototype satisfies the target sound, but the sound for the final product is set based on a consideration of the auditory evaluation of the prototype. In order to realize the target sound, the newly developed supporting system and the absorbing procedure are applied.

6. Future prospects for design for product sound quality

Design is an important element of product development [8]. On the other hand, the design greatly depends on the designer's abilities and standardization is insufficient. It is therefore necessary to clarify what the requirements are at the design stage in order to develop a product strategically and efficiently. The design for product sound quality is one of the best examples of top-down design. Lyon mentions the importance of the design for product sound quality [9], and also refers the difficulty of realizing that. The difficulty comes from the quantification of the ambiguous customer's needs. The physical evaluation can be done by four basic SQ (Sound Quality) metrics, but these metrics cannot be applied to discontinuous sounds such as a copier sound. The physical metrics to define discontinuous sounds should be developed to extend applicable products for the design for product sound quality. A lot of technical issues exist for realizing the design for product sound quality, but the most serious problem is innovations of the product development environment. It is important how to change the design philosophy to lead innovations [10].

7. Conclusion

In this paper, features of consumer product design were first described from the perspective of the design of Worth. Next, we introduced the Extended DfX methodology to enhance DfX (Design for X) that was already established for consumer products. We also introduced a practical example of trade-off analysis and the satisfying design that is the key technology when Extended DfX is applied. Moreover, the design for product sound quality is also introduced as the another approach for the design of worth.

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The Significance of Asking the Question “What is Design?”

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1. Introduction

I started studying design at university. After a short while, I became able to make things with my own hands, and to express the form that I had in my head as images. While I was acquiring those skills, a question gradually emerged inside me. That question was “I wonder why that form was expressed?” Over time, that question expanded into the question “What is design?”

What was it that I was seeking when I posed that question back then? It was a fact that I felt that it was not enough to make things just by using my hands, a ruler and a compass. Why did I think that I wanted to try and make things using the tool called thinking? At that time, I must have had thoughts like these : I want to ask the question “What is making?” I want to have friends whom I can sound out, and a place where I can ask that question. However, I was not able to find a formal place in the university education system at that time or in my design practices in the field where I was able to give serious thought to that question.

In this paper, I will present this question and relate my personal experiences as I sought the answer to it. I will then move on to considering the significance of questioning what design is.

2. Learning Design

The reason why this question arose is due to the existence of friends in my high school days who became mirrors that reflected me. At that time, my friends also pursued various fields of learning in their respective locations, and were respectively constructing their learning. When I met with them, I often listened to their stories and also told them things about myself.

“Mmmm, I draw sketches and plans, and I am creating various things.....It is very interesting.” Words like that, words that did not make sense even to me, came forth from my lips. Drawing sketches and plans are the means of design. Creating things are the goals of design. However, when we draw something, what on earth are the design problems that we are dealing with? When we draw something, what are we creating?

Even when I posed that kind of question to a design professor, I did not get the answer I wanted. Draw sketches, draw plans, create things somehow or other. That kind of pattern continued day after day. At that time, I began to think that I should start over and study something else. Design is work that considers only the surface of a thing, the arranging of the appearance of the target object.

If design is only that, then the work that we call design is trivial. Studying design may not hold an important significance for me. I first began to think like that during a discussion that I had one day with one of my seniors. His words cut me to the quick. “Your concept of design is not true design. Design is not about that.”

To be sure, design work excited us students. We can create an image of an object that is not before our eyes, and delineate that form. It is the coming into being of something unknown. And, it is the shaping of that something with one’s own hands into a functional device. What is interesting about this work is that we cannot say what the problems are that we are dealing with, but there is no doubt that they resonate with our concerns. The problems being dealt with there are definitely not trivial problems. Supported by those words, that change of mind was born inside me.

From there I come to the question of what are the problems that are inherent in design. I can sense these problems when I am designing something, but why is it that I cannot explain this in words? The journey to search for that answer began in my design practices. Projects, graduation, employment−my journey in pursuit of that answer continued throughout my work as a professional designer. I was able to obtain something like an answer in the middle of a project around seven years after I first asked the question “What is design?”

That project was the design of a piece of medical equipment that I was in charge of in 1978, an electrocardiographic recording instrument designed for use in group medical examinations. At that time, the instrument with a newly built-in computer was called “electrocardiac/heartbeat processing device”. This project was carried out by a team that consisted of experts from five fields under a project manager. The project team consisted of experts in the fields of marketing, chassis design, data processing software, software architecture and product design. There were two product designers−myself and one of my colleagues.

In the project’s basic design phase, we proposed an innovation to the frontality of the instrument. In other words, we proposed that the side with the screen that was used by the operator should be the front of the instrument from the operator’s point of view. And, we also proposed that the side facing the people who were undergoing the group medical examination should be the front from their point of view. An instrument with two front panels−that was our proposal.

This proposal was something that developed out of a survey carried out by the product designers in which we observed a group medical examination that was performed using current equipment at an elementary school. What we noticed was the anxious expressions on the faces of the children. When they entered the school infirmary, the children were met with a row of instruments that had a large number of cables sprouting out of their rear panels, cables that looked like snakes. The children seemed to be frightened at the thought of having one of those cables connected to their own bodies.

Our idea was born out of this realization. It was an idea for an innovative design where the instrument would have an additional face turned toward the children undergoing the medical examination, a design that newly incorporated a second front panel. One answer to my question “What is design?” appeared in the meeting to propose this design.

3. Discovering that answer

The presentation of several design proposals is an important part of the process involved in developing a design for a product. In our tradition of design development, it is customary for the client to select the final design. The three design proposals for that medical instrument that we presented to the team members met with their approval. The next step was the selection of the best proposal by the project manager. We were convinced that that was going to be the case.

However, what happened next was something completely different, something that we designers had not experienced before. The project manager said, “I want the designers to select the best design. We don’t know anything about design, and so that is why we asked you to participate in designing the product.” I felt as though I had been hit over the head with a baseball bat when I heard these words.

When I thought about it, indeed it was only the designers who had carried out the group medical examination survey. The marketing, chassis design, data processing software and software architecture experts accepted the proposed frontality innovation, but coming up with ideas and then selecting one of them as the final proposal was not their responsibility. The designers created those ideas, and so the responsibility was theirs.

This itself is one of the “problems that are inherent in design”. That is what I realized. What is important to us designers is the observation of the activities of people, the realization of how they came about, the discovery of problems, and the solving of those problems. These are all design problems that only designers deal with.

The other experts made us realize that the very considerations of designers are design issues themselves. That led me to the following verbalized explanation. Namely, the essence of the problems that are inherent in design does not lie in the sketches that were drawn or in the form of the thing that is completed, or in other words, the “results”. It lies in the relationship between people and instruments. The creation relationship itself is a design problem, and the materialization of the relationship thus created into the form of a thing called a instrument is the design process.

When I realized this, I went to the company library and searched through an enormous amount of design document files. Sketches, plans, models and photographs of completed works created by older employees and colleagues, as well as minutes of meetings, are all on file there. However, amongst those materials I was not able to find any descriptions, that is, design discussions relating to the basis for the argument of form, about the “relationship” between things and people, a concept which should have been the nucleus of these creations.

However, there had been no language developed to provide an “explanation” of the design problems that are the basis for the argument of designing. The reason for this is because there had been no concept or language developed to describe design itself. At that time, I was convinced of this, and felt that I needed to obtain the knowledge required to develop the concept and language to explain design.

Clarifying the design problem referred to as “the relationship between people and things” just by creating one design after another is undoubtedly a difficult task. In order to grasp the problems that lie behind design, language that can perceive and explain them is required. Furthermore, I felt sure that if there were another different type of language, I would be able to use it to directly deal with and put together design problems. So then I decided to move the location for considering those things from the design front line to graduate school. At that time, I started activities toward constructing a study of design that would clarify the way in which design problems came about.

This kind of personal experience is linked to my current activities of developing a new framework to coordinate design education, research and practice, and a framework where concept and language go hand in hand with the creation of form. In the midst of all this, I recently started to realize something.

That something is the new wall that I have come up against in the midst of perceiving and clarifying design problems. Language that can perceive and explain design clarifies the issues inherent in design. However, there is a dilemma in that unless the aforementioned design activities to return it to its origins do not occur there, that language will not bring to bear any tangible meaning or value socially.

If I were to describe this dilemma as an actual issue that I am currently facing it would be as follows. For example, at the initial stage of a design educational curriculum, even if we determine what the design problems are and offer the students a concept and language as knowledge to deal with various design problems, most of them do not show any interest. Rather than descriptions of the problems that become the nucleus of design, their interest lies in expressing objects as things that exist before their eyes. In design, the act of expression is the first target, and, in the same way, it is also design’s ultimate target. Moreover, the design students’ interest always lies in the act of expression.

The explaining of design problems is always linked to expressing things regarding design. That has become the premise for asking what design is. This is the contention of this paper, and I would like to discuss this in the second half.

4. Doing and Knowing

In their concept of “Situated Learning”, Brown, Collins and Duguid identify the separation between “what is learned” and “how it learned and used”. In their argument, they draw attention to the problem that “knowing” and “doing” are handled as completely separate issues. The following quotation is what they assert [1].

Many methods of didactic education assume a separation between knowing and doing, treating knowledge as an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used. … The activity in which knowledge is developed and deployed is not separable from or ancillary to learning and cognition [1].

If we perceive the learning of design that lies underneath these viewpoints of “knowing” and “doing”, the characteristic inherent in the learning of design become apparent. That characteristic is that design is learned in the sequence of “doing (trying)”, then “knowing”. It can be said that this sequence of “creating something unknown” connotes the essential mechanism of design.

From this viewpoint, I would like to interpret my personal experience mentioned earlier as follows. Namely, in a design educational program, students gradually become able to create designs while “doing”. Then, the question of what is design manifests itself. That is the grasping of design problems through “knowing” and the desire to develop design from that knowledge. After I had graduated school and had applied myself to practicing design through “doing”, I grasped the answer to my question one day at the design front line. That revelation was that design is the creating of a relationship between the artifacts produced and the people who are affected by the artifacts.

“Doing” seeks “knowing”. A concept that has been produced from “knowing” is once again embodied through “doing” and realized as actual objects and things. These two acts are linked to form a whole. However, the status quo is that the field of design has “doing” at its center, and “knowing” is not included in that process. A large number of universities have failed to expand their design educational programs to include “knowing”. It goes without saying that this status quo is in need of reform. However, profound thought will need to be given to how these two types of intelligence can be incorporated.

I wonder why the field of design has “doing” at its center. Becoming able to create things as design is similar to becoming able to ride a bicycle or becoming able to ski. This similarity lies in the fact that the person attracted to the action in question becomes able to do it through using his or her own body and actually trying to do it.

Learning such skills in the reverse order is difficult. For example, very few people can become able to ride a bicycle without any practice just from the knowledge gained by reading about the structure of a bicycle.

You grip the handlebars of your very own bicycle that you have wanted for a long time and have finally gotten. You then straddle it, and propel it forward. You can only become able to ride a bicycle by trying to ride it. Yes, riding a bicycle, skiing and creating designs are all achieved through working at "doing" it. Surely it is natural to start by "doing" in order to become able to do those things.

And, when you gradually become able to ride your bicycle, you start to think ahead about enjoying your bicycle, about riding it somewhere with someone, about how to ride it. Questions emerge. From that point, a person who has a bicycle encounters the essence of a bicycle as a mobile tool and becomes fond of it. Thus begins a lifestyle where the bicycle is widely used. The design process is the same.

Therefore, it is important to place the asking of the question "What is design?" within the domain where design is done. Design that starts from "doing" leads to "knowing", and encounters the problem that is its essence. It deals with those problems themselves, and this leads to a design that puts them together. The knowledge that has been put together there is once again returned to the design as "doing". Then for the first time "knowing" and "doing" link the design, resulting in the design being brought up to a higher dimension as "doing".

That is a design where that process is manifested together with the results. However, it is not easy to externalize or make visible the processes of thought and action that develop within a designer's work. The "knowing" part of a design is nothing but the use of words to clarify both the flow of the thoughts and discussions of the people who take part in the design process, and phenomena that arise and disappear such as the problems that can be perceived there. If those things become clear, in addition to the products that are thought up and brought into being, a further product called the knowledge of design is sure to spread out into society.

5. Placing "knowing" inside "doing"

There are two questions involved in the theme of this paper "The significance of asking the question "What is design?" ".

The first question seeks to know what the target of design is, and to know how design designs that target. The acquisition of that knowledge becomes the substance for explaining what design is. However, that explanation itself is not directly linked to "doing" design. The questioning of design by no means ends there when the answer to that first question is obtained. That fact is expressed in the above-mentioned example of a bicycle. You can know what a bicycle is without riding it. However, a bicycle exists for people to ride it, not for people to know what a bicycle is.

Design is all about doing design in this society, and presenting the resulting products to society. In other words, the asking of the question "What is design?" and the "knowing" about design from that question links design to "doing", whether we like it or not. Here, we can see the shape of the answer to the second question.

In other words, the significance of questioning what design is can be found here. It can be said that that significance is the asking of this question in order to return the "knowing" of "what is design" that was discovered through doing design to "doing" design, and to move from there to thinking up and bringing into being objects and things as the fruits of design in a higher dimension.

In order to ask the second question, it is necessary to construct a mechanism for returning "knowing" to "doing" and a place for practicing that. There, the true meaning of "knowing" design and its value should become apparent. Knowledge is born out of questioning the real world of lifestyles and work, and is there for the purpose of once again being returned to that real world. And so, I believe that we must construct the study of design as knowledge that contains a mechanism for returning it to the real world.

In doing that, design creates what the scheme of things in the real world should be, and its mission is actually arranging that scheme of things. That is what design is. And, by adding "knowing" to "doing" in design, at last a real design can be constructed. That design is undoubtedly not only the creation of the designer, but should also become the intelligence of the people who are universally trying to shape their own society. I believe that constructing a study of design consists of making the doing of design the nucleus of the study.

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Designing Language Games

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Abstract

This paper shows that traditional language games are governed by linguistic principles and thus speakers avoid deviating too much from their linguistic knowledge. We also show that speakers can consciously challenge part of linguistic systems and rules by designing a novel language game. Two of the traditional language games in Japanese, dajare and shiritori, will be described to illustrate the effect of linguistic principles on language games. We will then introduce a hitherto undescribed language game designed as a conceptual art, and see how it is created through the balance and tension between creativity and unexpectedness on the one hand and grammatical well-formedness and meaningfulness on the other. Designing language games-or studying designs of language games-may tell us a lot about the nature of our creativity.

1. Introduction

People play with their language(s) all the time, a practice referred to as "language games". People enjoy finding out similarities in sounds of words (punning), recalling words with similar meanings or sounds (*rensoo geemu* 'association game'), trying to utter phrases that are difficult to pronounce (tongue twister), creating new phrases by changing the order of letters or sounds, etc. Language games are widespread among different language communities, and different language communities have different language games. Some of them are traditional, and some of them are innovative. In Japanese, we have, for example, *shiritori* (the players say a word which begins with the final mora of the previous word), *kaibun* (palindrome), *dajare* (puns), *goroawase* (puns especially for numbers, often used as mnemonic or just for fun), to name just a few. In this paper, we show that traditional language games are governed by linguistic principles and thus speakers avoid deviating too much from their linguistic knowledge. However, we also show that speakers can consciously challenge part of linguistic systems and rules by designing a novel language game.

In the rest of this paper, we develop our discussion as follows. Section 2 describes two of the traditional language games in Japanese, dajare and shiritori, to illustrate the effect of linguistic principles on language games. Section 3 introduces a hitherto undescribed language game designed as a conceptual art, and see how it is created through the balance and tension between creativity and unexpectedness on the one hand and grammatical well-formedness and meaningfulness on the other. Section 4 concludes the paper.

2. Traditional language games in Japanese

2.1. Dajare (puns)

Dajare is very common among Japanese speakers. In typical cases, speakers compose *dajare* by creating sentences or phrases using identical or similar words, as in (1) and (2).[+1]

(1) Arumikan-no ue-ni aru mikan.
aluminum can-GEN top-LOC exist orange
'An orange on an aluminum can.'

(2) Aizu-san-no aisu.
Aizu-from-GEN ice-cream
'Ice cream from Aizu.'

The example in (1) involves an identical sequence of sounds, [arumikan]. The second example on the other hand involves a pair of two similar phrases, [aizu] and [aisu], where the corresponding consonantal pair [z]−[s] involves non-identical−yet similar−consonants.

In my previous projects with Shigeto Kawahara, we have investigated linguistic principles that govern Japanese puns,

[+1] Speakers can also change an underlying form to make it more similar to the corresponding word. For example, in *Hokkaidoo-wa dekkai do* 'Hokkaido is big', speakers change the sentence-final particle /zo/ to [do] to make /dekkai zo/ more similar to [hokkaido]. Other types of *dajare* include those that hide the first element and let hearers guess what it is. Many of this type of *dajare* are made by replacing a part of proper names, clichés, or famous phrases with a similar sounding word. For instance, we find a pun like *Maccho-ga uri-no shoojo* 'A girl who's proud to be a macho', which is based on *Macchi uri-no shoojo* 'The Little Match Girl'.

especially cases like (2) which involve non-identical pairs of sounds (imperfect puns) (see [1] for a review). By way of corpus analysis and experimentation, we have found that in making puns, Japanese speakers attempt to maximize the similarity between the corresponding words. This principle holds true both in terms of vocalic similarity [2] as well as consonantal similarity [3][*2]. Another study of ours has also found that both psycholinguistic and phonetic prominences affect the measure of similarity deployed in the formation of Japanese puns [6]. These results show that speakers do not necessarily randomly combine words to make funny sentences, but they care about the phonetic/phonological aspects of pun sentences.[*3]

2.2. Shiritori

Shiritori (literally "bottom taking") is a language game in which the players need to come up with a noun that begins with the final mora of the previous noun [9]. Participants take turns, and the person who says a word ending with a coda [N] or repeats a noun that has been already said loses. An example of a series of words produced in shiritori is : *ri**su*** (squirrel) => ***su**zu**me*** (sparrow) => ***me**da**ma*** (eye ball) => ***ma**ru**ta*** (log) => ***ta**ta**mi*** (room mat) => ***mi**kaN* (orange). The person who said *mikaN* loses.

Although this principle of *shiritori* is simple, some groups of people use different local rules, because different interpretations are possible with regard to what counts as "the bottom". If the last letter (in Japanese orthography) is taken as the bottom, *kaisha* (company) => *yakyuu* (baseball) is allowed because in Japanese writing system, the last letter of *kaisha* is the same as the letter representing *ya*. If the last syllable (or the mora) is taken as the bottom, *kaisha* => *shachoo* (president) is allowed. If the last mora is the bottom but the last syllable is not, *shachoo* => *oni* (goblin) is possible but *shachoo* => *choori* (cooking) is not allowed. Each group playing *shiritori* can adopt one or more of these local rules. Although we observe a variety of options, these rules are all based on linguistic principles ; Japanese writing system or Japanese phonology.

Some people add further restrictions on *shiritori* as well, some of which are semantic. Some players for example like to limit the nouns to be of a specific genre or associated with a specific topic. Limits can also be imposed on lexical aspects : proper nouns are usually not allowed, and compound nouns are largely restricted except when they are fully conventionalized or lexicalized. One of the other intriguing phenomena is the fact that nouns used in *shiritori* are very frequently those belonging to so-called "basic-level categories" [10-12].

In summary, both *dajare* and *shiritori* are governed by linguistic principles. Some of the principles are unconscious (the similarity restrictions on punning) : others may be conscious but easy to understand and follow (the local rules in shiritori). This property of language games does not come as a surprise because if the principles and the rules are complex−or against our linguistic intuition−playing such games would require too much effort and participants may not have fun. For this reason, traditional language games tend to be intuitively understandable, easy, while allowing for much freedom.

Now we would like to raise the following question : can we consciously design a language game that is substantially different from traditional language games? Although it is quite easy to modify the rules of traditional language games or add optional rules to them, is it possible to create a novel language game? The answer to this question is 'yes'. In the next section, we will look at a different kind of language game, i.e., a novel language game designed by a particular person or a group.

3. Hiragana kookan (Hiragana exchange)

3.1. The system of *hiragana kookan*

Taiichi Uchiyama, a Japanese modern music composer and conceptual artist, designed a language game called *hiragana kookan* (hiragana exchange). The system of this game is similar to the traditional Japanese literary game *renga* (two or more people write lines of a poem in turn), but unlike *renga*, the unit in *hiragana kookan* is designed to be as small as possible− participants can write only one hiragana at one time (a hiragana represents a mora or in most cases a syllable consisting of one vowel or a consonant plus a vowel ; one hiragana can represent, for example, [ka] or [bo], which requires two letters in alphabet, or a single vowel like [a], [i], or [u]).

The rules of *hiragana kookan* are simple : two or more people participate, one of them writes one hiragana on a sheet of paper and passes it to another person, who adds one hiragana to make a meaningful phrase, and then participants go on in the same way in turn. In so doing, participants are not allowed to tell other participants what words or phrases they

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[*2] English pun patterns show similar properties [4,5]

[*3] Previous studies have argued that linguistic principles govern other kinds of language games, such as *zuuja-go* (Japanese musicians' argot) [7] and the *babibu* language [8].

are thinking of when and after they write their own hiragana, although when a text is finished, participants discuss what they intended and how they interpret the text. Since this "silence rule" makes it impossible to communicate one's intention to the others while creating the text, the result of this activity usually becomes a very unexpected one for the participants. For example, imagine that three people are participating in *hiragana kookan.* One participant writes wa, and then a second participant adds ta. At this point, a meaningful word *wata* 'cotton' emerges. The third person may adopt this interpretation and continue a sentence, or try to think of some other word that begins with *wata* such as *wataridori* 'migratory bird' or *watashi* 'I'. Imagine the third person writes *ri*, and the sheet returns to the first person. What actually happened was that the first person could not think of any words or phrases that make sense starting with *watari* but only an actor's name 'Watari Tetsuya' came up to his mind, so he wrote *te* after *ri.* The second person sees *watarite,* but he did not understand it at all. Situations like this often occur and participants sometimes have a tough time trying to continue a phrase. One interesting aspect of this game is that we experience how different words/phrases other people come up with given the same sequences of sounds.

The following example (3) is a part of a result of *hiragana kookan* played by three people. [13, p.7] A, B, and C represent the three participants ; hyphen separates each hiragana's sounds.

(3) **すみをすりおえふとふでをとってもちにくいをさわがしくさすよ。**

Su-mi-o-su-ri-o-e- fu-to-fu-de-o- to-t-te
A B C A B C A B C A B C A B C
mo-chi-ni-ku-i-o-sa-wa-ga-shi-ku-sa-su-yo-(period)[+4]
A B C A B C A B C A B C A B C

By its nature, *hiragana kookan* does not necessarily produce interpretable sentences. In this example, however, one possible reading may be ; 'Having finished making ink, I am picking up a large writing brush and sticking a stake noisily into a rice cake.' Several other interpretations are possible. The

[+4] An optional rule allows players to put a comma or a period instead of a hiragana letter. The original members of *hiragana kookan* (Taiichi Uchiyama, Kazuko Shinohara, Shin-ichi Yamamoto) adopt the exceptional rule that one can write a hiragana followed by a comma or a period at one time but not a comma or a period followed by a hiragana [14, p.20].

phrase *futo-fude* 'a large writing brush' can be broken down into two phrases *futo* 'unconsciously, absent-mindedly' and *fude* 'a writing brush', and this changes the meaning of the sentence : 'Having finished making ink, I am picking up a writing brush absent-mindedly, and sticking a stake noisily into a rice cake.' This kind of ambiguity or the possibility of multiple parsing is an ordinary phenomenon even in daily use of language, so it may be uninteresting. The latter part of (3) gives us more implication. The part *mochinikui* can be interpreted as 'hard to hold' if it is not followed by *-o* (accusative marker). This interpretation is contextually natural because the first half of the text says that the person is picking up a writing brush. Thus, if we see only the first half of this text up to *mochinikui*, we will not ordinarily think of sticking a stake into a rice cake. The person who wrote *-o* destroyed this whole context, and it was intentional (the participants discussed what they did after finishing this text and the person who wrote *-o* confessed that he did it intentionally, while the other two were imagining that the phrase would continue like *mochinikui-to tsubuyaku/omou/kanjiru* 'say/think/feel that it is not easy to hold'). This is a typical phenomenon that occurs in *hiragana kookan* : a participant can change the whole context or destroy the grammatical well-formedness, semantic consistency, or contextual naturalness totally by putting only one letter, and nobody can predict who will or will not do this until it actually happens.

(4) is another example, which was written by four people [13, p.5]. The sequence of hiraganas produced by the players is shown in (4 a) ; English gloss and rough translation is shown in (4 b).

(4) a. **ゆくえのしれぬぼうふらは、きのりのしるし。**

yu-ku-e-no-shi-re-nu- bo-u-fu-ra-wa-(comma)
A B C D A B C D A B C D A
ki-no-ri-no-shi-ru-shi-(period)
B C D A B C D D

b. yukue-no shirenu boofura-wa, kinori-no shirushi.
whereabouts-GEN unknown wriggler-TOP 'kinori'-GEN sign
'The wriggler whose whereabouts is unknown is the sign of kinori.'

The hardest part of this text is the phrase *kinori-no shirusi.* There is a word *kinori* in Japanese, but it is used negatively as in *kinori-no shinai* 'don't feel like doing/reluctant/halfhearted'.

Thus, three of the four participants, A, B, and D, expected the phrase *kinori-no shi* to continue as *kinori-no shinai.* Only C did not hit upon this phrase but he interpreted *kinori* as *ki* 'tree' plus *nori* 'glue', and imagined some kind of pitch-like substance on the surface of a tree. C thus added *ru* after *shi* to make a word *shiru* 'liquid/juice'. For C, this was a natural association given the word *boofura*, i.e., mosquito larvae, which grow in sewage. However, D could not make sense of *kinori-no shiru,* and in perplexity, she put an end to the phrase by adding *shi* to make *shirusi* 'sign' and a period, according to the rule they used (see footnote 3). The phrase in (4) was created in this way.

In *hiragana kookan,* accidents like this not only occur within a word, a phrase, a sentence or in a line, but also discourse may get disturbed due to such miscommunications. Participants try to "read" other people's mind and try to make sense of the text. Nevertheless the outcome sometimes only becomes ill-formed or incomprehensible, or sometimes extraordinarily funny. The funniness of the texts produced by *hiragana kookan* is something a person cannot create intentionally ; it is a very strange strangeness. It may be because this system is designed to prohibit each person from controlling even one word at his/her own will, and to incorporate "other minds" even in determining the boundary of one word.

3.2. Implication of hiragana kookan to collaborative art

As we have seen in section 2, traditional language games are fundamentally governed by linguistic principles and intuitively easy to understand. *Hiragana kookan* is not an exception in that it relies on players' linguistic intuition. The unit exchanged in this game is hiragana, which represents a mora in Japanese. In this way, it relies on players' ability to control moras. However, *hiragana kookan* is a novel language game in that it exchanges elements that basically do not have meanings in themselves. Moras are bigger units than phonemes, but they are not meaningful. Putting one hiragana cannot totally control the meaning of the text, even a word or a phrase, nor can it totally control the grammatical structure of a sentence.[*5] This imposes a strong restriction on the players' control over the text they are producing, and this restriction of control can induce unexpected results that go beyond a person's imagination or association, or of course a person's intentional deviation from grammaticality as a rhetorical technique. Grammatical well-formedness is often destroyed or shaken in a curious way, and in this sense too, *hiragana kookan* is different from traditional language games.

Uchiyama designed an exchange system like this first as a way of experimental musical composition, where each one of two persons writes only one note on a music sheet in turn. He noticed that this method produced very strange music that a single person could not imagine by him/herself. He saw what happened when "other minds" came to interplay in a process of creation. Then he extended this idea to writing, and Shinohara employed it as a system of experimental poetry [15, p.32−34].

Collaborative poetry writing like *renga* has a long history in Japanese literature, but in *hiragana kookan,* the unit is made as small as possible (there are smaller linguistic units such as phonemes, but hiragana seems to be the smallest possible unit that can be used without much stress, since ordinary speakers of Japanese will have difficulty in thinking of and writing phonemes or alphabets). By making the unit small enough, it becomes easy for "other minds" to be incorporated and thus more unexpectedness can be induced. The unexpectedness induced by this game includes breakdown of grammatical well-formedness : sometimes participants cannot rescue the text from collapsing grammatically. Even in such cases, grammatical rips in the text can be fun and enjoyable because they are often unexpectedly strange.

Another interesting effect of *hiragana kookan* in poetry writing is that author's identity is shaken in this language game. In *renga*, the authors are well aware which part of the poetry they wrote and with what intention or feeling. On the other hand, in *hiragana kookan,* we cannot identify who wrote which word or phrase, since players collaboratively write even one word. Even when an uninteresting, poor text is produced, it cannot be attributed to a single person. Actually, participants in *hiragana kookan* tend not to feel that the text they wrote are *their* original text. They feel as if some other person(s) wrote it. This is a curious experience especially for those who are obsessed by the idea of self-identity.

4. Concluding remarks

Linguistic principles govern conventional as well as innovative language games. At the same time, speakers can consciously challenge part of linguistic systems and rules by designing a

[*5] Some hiraganas have more grammatical information than others : since *-o* （を） is an accusative marker, it has more grammatical information than most other hiraganas. Particles like *-ha, -he, -ni, -ga,* and others can also convey grammatical information if put in a proper place.

novel language game. Designing language games−or studying designs of language games−may tell us a lot about the nature of our creativity.

Appendix : Sample texts of *hiragana kookan.*

1. A poetry line produced by four poets

(February 6, 1988, by Manabu Okayasu, Seiko Naradate, Naoko Shinozawa, Ben Kurao.)

われかかあのみを、あつめぼうぼうくるひのこみたついせんが、やみいるもうもくをしいらぬ。

2. A passage produced by two players

(January 8, 1989, by Kazuko Shinohara and Shin-ichi Yamamoto)

どれみふぁそーそふぁみれどしらしらないよ、くらべてみたら、のっぽのおじさんがにこっとわらってぴえろのようなかおをだした。ぬんぼうといしぼうと、いまごぼうとへちぼうが、こやのなかでいっしょにうどんをたべながらせいばつにでかけようとそうだんしていた。きびだんごもひとつずつくびにぶらさげ、あかいまえかけをつけて、あしおとかるくどらをならし、どうぶつたちをかどわかし、おまいりもすませてさあしゅっぱつ！げんじぼたるがいっぴきすかしたひもをひっぱると、くらいよぞらもぱっとあかるくなった。あまのじゃくなぐんじんが、それをみていじわるをしようとたくらみ、まえばをむきだしておっかないかおをした。ぬっ、こいつめ！やっとあかるいよぞらからにげだせば、こばんざめがでてくるじかんとなった。せぶんもひまをもてあまし、べつのほしからやってきた。だいきぼなせんとうがくりひろげられ、せいふもかいにゅうし、せかいてきなげんじぼたるぶりとなった。ああ、いつもこんなことをよくやっているな。いまごろは、せいじかもびっくりしていることだろう。なみだながらにうさぎのだんすをおどっていますと、のべのしらべがつたわってきます。ぬすっとのしらをきるすがたに、あきれはててしずかにたちばをまげるのを、つたのからまるちゃぺるでけんがくしているうさぎさんも、れいぎただしくおそろしく、みんかんじんからたのもしくおもわれていました。こばんざめといっしょに、でっぱつりあげ、よのなかをひていてきにみてみたいとおもいだすのは、きょくたんなかんがえかたかもしれない。のっぽのぴえろも、いっぽずつじぶんのみちをふみしめて、ゆっくりとあゆむようにとさとされたようである。

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Now More Than Ever – Computational thinking and a science of design−

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Abstract

Revolutions in desktop manufacturing and embedded computing are changing the way we make things. These changes will enable citizens to engineer and manufacture their own goods. The role of the designer is also changing, deciding on the manufacture of specific artifacts, to setting the bounds and rules for decisions that end-users make. Materials are changing tool : Programmable matter made of ensembles of modular robots demands new and dynamic ways of describing designs. A science of design is an essential element for benefiting from these revolutions, and it is likely that a science of design will be expressed computationally.

Keywords

Computational thinking ; programmable matter ; end-user design

1. Introduction

Forty years have passed since Herb Simon wrote his influential The Sciences of the Artificial in which he coined the term, the Science of Design [1]. At that time, in the late 1960 s, people had a growing sense that the world we make and live in was growing so complex that the traditional ways of designing were no longer adequate to the task. If it was true then, it is truer today.

Yet for the past several decades, design research has been viewed with some skepticism. Many look down on design research, believing that (in the words of Alexander's 1971 preface to his Notes on the Synthesis of Form), "People who study design methods without also practicing them are almost always frustrated designers who have no sap in them, who have lost, or never had, the urge to shape things. Such a person will never be able to say anything sensible about "how" to shape things either" [2]. Within the engineering community, too, the idea that there might be a "science of design" has met with some skepticism. Many excellent engineers believe that research on design is a 'soft' field of study. They believe that engineering design is driven by the properties and behaviors of specific domains. They think that other than a need for "proper thinking" there is little interesting that we can say in general about design.

With due respect to these doubts, in light of the revolutions in manufacturing and technology that we are now experiencing, we can no longer afford to view a science of design as soft or as an irrelevant intellectual game. Rather, a science of design is a necessary foundation for the changes that are already beginning to pervade our everyday lives.

First let us clearly draw a line between the "science of design" and the "science of designers". Both (but especially the latter) have been the subjects of a great deal of research over the past several decades. The science of design is the study of design processes, regardless of who, or what, is doing the design. For example, researchers may investigate how a space of designs can be efficiently searched, or how a notation or language can compactly express a class of designs. The science of designers is the study of human designers, how they think, what they do, and how they communicate. For example, researchers analyze designers' drawings, ask designers to think aloud as they design, and videotape designers working together in groups [3]. Both fields of study are interesting, but they are quite different enterprises.

2. Radical changes in how we make things

Today we are in the early stages of a profound change in the way we design and construct our physical world. It is not the first time this has happened. Christopher Alexander tells this story in Notes on the Synthesis of Form [2]. At the beginning of the industrial age in the late 18 th century our society moved from individual craftsmen making artifacts one by one, to assembling (by hand) objects from standard components, and thence to mass production in the 20 th century [4]. With each shift in production has come a corresponding shift in designing. In the age of craft, design was implicit−based on a shared understanding of common goods. When you needed a new gate or a hammer you went to the blacksmith and explained what you needed and he made you one. The industrial age brought the need for explicit designing to consider the function of the artifact and to plan the materials and methods of producing it. The designer or engineer made paper drawings and models to plan the artifact. When the designing was done the drawings were used for manufacture. Mass production made design even more necessary, as high costs of tooling and setting up manufacturing lines demanded that we thoroughly think through an artifact before beginning to make it. Today, designers no longer use paper drawings to conceive, consider, and convey their designs. Instead, files are stored and transferred electronically from designer to manufacturer. Still we are mostly in the mode of making drawings and models to design the artifacts we desire.

Each shift in the design and production of our physical environment has resulted in broad and profound impacts on our society in myriad ways (health, education, social and economic order) that would have been almost impossible to predict. There is every reason to believe that the changes of our time will have even broader societal impact than those that have come before. The fundamental change in manufacturing and production that we are in the midst of now has the capacity to enable and empower ordinary citizens in ways that have never before been possible. By leveraging the science of design, the engineering of desktop manufacturing, and the software to bring the two together, we can make the vision of “democratizing innovation” [5] come true. I will argue that it is the software, and particularly computational ways of expressing design knowledge and expertise that will bring this dream to reality.

The shift in the production of the physical world derives not from a single technological advance but from developments in several arenas : computer controlled tools (e.g., desktop manufacturing), embedded computing, and science of design.

3. Desktop design & manufacturing revolution

Already underway is the shift to desktop manufacturing − people can afford to design and manufacture one-off artifacts for themselves. An early example was desktop publishing. Before we invented laser printers if you wanted a brochure, a newsletter, or a poster you worked with a graphic artist to design a layout, select typefaces, paper, and so on ; and then with a printer who would execute the design and produce the final inked paper product. Today laser and inkjet printers are practically free, and using desktop software anyone can design and print their own newsletters, calendars, wedding invitations, and even books. The desktop publishing revolution was driven first by the development of laser printing technology. Application software enabled professionals at first, and eventually end users, to produce graphic work. A key component was the underlying Postscript language that applications use to produce page descriptions for laser printers.

Laser and water jet cutters, three-dimensional printers, and computer-numerically controlled milling machinery are now extending this shift from the mostly flat world of paper and graphic arts to the richer three dimensional world of physical objects. The first (or second) generation of hardware to support this revolution in “desktop manufacturing” is already commercialized and capabilities continue to advance as costs drop [6, 7]. The specific technologies vary from laser sintering to fused deposition modeling, but we are clearly moving along a trajectory from single material (e.g., plastic or metal) to multiple materials, to the ability to manufacture−in small quantities− unique physical objects with embedded electronic circuitry, printed displays and other actuators (http : //fabathome.org ; http : //www.2objet.com). As with desktop publishing, software plays a key role : Computer-aided design and engineering applications to describe physical objects and simulate their behavior, and the underlying representations (analogous to PostScript) enable designers to do their work.

4. Embedded computing revolution

A second revolution−this one in computing−is also underway : We are embedding microcontrollers, actuators, and sensors into our physical environment, and the communication and control of these devices [9]. Advances in micro- (and nano-) electronics leading to low cost sensors and actuators, micro-controllers that are as powerful as yesterday’s mainframes, and new wireless communications protocols fuel this revolution. We see its impact in everyday lives as our clothing, our furniture, our buildings, automobiles, and cities become computationally enhanced. Applications are simple so far but already we have the capacity to make things that exhibit computationally complex behaviors.

The desktop manufacturing revolution applies here as well. As recently as a decade ago only an experienced engineer could design and manufacture a printed circuit board (PCB).

Today even a high school student can easily acquire the skills to design a board using off-the-shelf software and send the file to a fabricator for low-cost overnight manufacture. Inkjet printer companies are now envisioning affordable desktop PCB manufacture [8].

5. Design methods & science of design

In addition to advances in desktop manufacturing and ubiquitous computing, another relatively recent development is relevant : The recognition that the complexity of the things we make and their interaction in the world demands that we understand designing better. Although its roots go back further, in the mid-1960 s researchers−in what became known as “design methods movement”−began to recognize that increasing complexity demanded a comprehensive understanding of designing−in Simon’s memorable phrase, a “science of design” [1]. Although the focused intensity of the design methods movement faded, the agenda did not. Today the software engineering and human-computer interaction communities have embraced Alexander’s “Pattern Language” approach [9]. Horst Rittel’s “issue based information systems” [10] led to design rationale and knowledge management.

The recent US National Science Foundation “Science of Design : Software Intensive Systems” initiative [11] is further evidence that the needs that drove Simon, Rittel and others in the 1960 s and 1970 s−to understand designing in the face of increasing complexity−remain relevant today. We still lack a coherent fundamental science of design (an understanding of the structure of design decision making, abstracted from specific domains). Still, we have seen steady progress in modeling design processes and developing computational design methods and tools. As computer hardware advanced and more powerful programming environments became the norm, the early insights of the design methods movement took form in increasingly powerful computer-aided design (CAD) tools for architectural, mechanical, electrical, civil, and software engineering.

6. Code as the carrier for design expertise

The move, starting in the 1960 s, from design by hand to design with computer tools enabled us to begin to automate some of the reasoning and decision making that is at the heart of designing. One of the earliest examples, of course, was Ivan Sutherland’s Sketchpad program. Sketchpad is known for many things, but for the science of design, Sutherland’s most important contribution in Sketchpad was to describe a design as a set of constraints that the program could manage as the human designer made changes. Later, during the 1980 s and 1990 s, researchers in expert systems, case based reasoning, and other fields of artificial intelligence, followed this general approach and applied these ideas to design in many different domains−from buildings to circuits to software to machines. Advances in computer hardware and software during the 1980 s and 1990 s made it possible to implement the ideas that the design methods researchers had worked on in the 1960 s and 1970 s.

What is important about this piece of history is that software became the medium for carrying the methods and techniques that the early design researchers developed. In a kind of chicken-and-egg process, as the software became more sophisticated, designers in practice began to adopt it and depend on it. In some fields, notably integrated circuit design, the software began to embed automated design methods that human designers could not perform in reasonable amounts of time. Design knowledge and expertise began to take the form of code. Designers began to adopt computational thinking [12].

Still, during the shift from design-by-hand to computer-aided design, the dominant model has been the computer program as tool or assistant to the designer. The designer is in control and makes all the decisions. The computer has served mostly to record and display the decisions the designer makes, and to calculate, look up, and render information about the design. Although adopting computer aided design tools has affected design practice, so far we have experienced only a small departure from the traditional way of making design decisions. That is about to change.

7. End-user design and computational thinking

The revolutions in desktop manufacturing and in embedded computing push us towards computational ways of thinking about design. One example is end-user designing, now becoming popular as ‘co-creation’ [13]. End-user design is the idea that as we move away from mass-production and embrace the idea of individualized or ‘mass-customized’ manufacturing, ordinary citizens will be able to design and make things for themselves. We are seeing the first wave of co-creation, in which citizens (sometimes called “consumers”) participate in making decisions about a design. The examples are many, from shoes to cars to toys. (Although it is now becoming popular, enabling end users to directly make design decisions is an old idea : Beginning in the early 1960 s Dutch design methodologist N. John Habraken developed a theory and method for engaging citizens in the design of their housing [14].) End-user design requires professional designers to set up a design space that citizens can work within. They specify the rules that govern the end-user designs. (This too, of course, is a design act.) Today the design and production process is usually computationally mediated, so the bounds of the space and the rules that govern designs are also expressed computationally.

The advances in personal desktop manufacturing that are empowering end-users to design and manufacture their own goods demand advances in software. We need representations to describe designs and applications to manage and manipulate those representations. The representations are design languages that machines can parse, recognize, and process. The applications are compilers and other development tools. Instructions in a high-level programming language like Ruby or Lisp describe the behavior we want a computer to perform. Instructions in a high-level design language describe what we want of our design artifact. A design compiler takes high-level descriptions of the behavior and generates implementation in the form of an object. For example, a compiler might generate code that a 3 D printer, or other desktop manufacturing machine can execute to physically produce a design.

It might seem that this way of designing will limit creativity. The opposite is true. Computational descriptions of design will enrich, not impoverish opportunities for everyday creativity. It should be clear, then, that the way that the computational tools for design are configured will strongly color the ways in which citizens can be creative. Nakakoji has outlined an interesting and valuable framework for understanding−and designing−computational tools to support end-user creativity in design[15].

8. The programmable world

Another, perhaps even more profound, change is on the horizon : a physical world whose behavior that we can program. We already see microprocessors embedded into many of our everyday things−from clothing to transportation−and with that comes the ability to program their behavior. As our things and our world become enhanced with computation, we must find ways for citizens to program and reprogram their behavior. As with our end-user design story, citizens become designers of the dynamic behavior of things and places in the world.

A logical extension of the computationally embedded things we have today is a world built from ensembles of thousands of modular robots. Each robot would be able to sense its immediate environment, move itself and perhaps its robot neighbors, and communicate with other robots in the ensemble. The robots could be programmed to respond automatically to changes in their environment, or to change configurations on command. For example, a building made of robot building blocks [16] could reconfigure itself to adapt to different weather conditions, different uses, or to respond to emergencies such as earthquakes, fires, or floods. Although making this idea a reality may seem far in the future, several research groups are developing the core technologies for “programmable matter” today [17−19].

If programmable matter becomes an everyday reality, how will we design for it? As we saw with end-user design, the role of the professional designer will change. No longer will the job of a designer be to make informed decisions about a specific artifact. Instead, the job of the professional designer will be to program the artifact’s dynamic and responsive behavior. Or rather, to program the dynamic and responsive behavior of the ensemble of modular robots of which the artifact is made. To the designers of today, this may seem a quite different kind of job than what we usually think of as design. Really, though, the designer’s task will still be−as it always has been−to create things that meet certain needs. The difference is that instead of creating the things directly in a “one-off” fashion, the designer will program the materials to respond to different conditions.

9. Discussion

We began with a reference to Simon’s lecture on the Science of Design. Simon made his remarks at a time of great social and technological change around the world. We are today again at a time of great change : enormous challenges face humanity−climate change and its effects, the need to feed a growing world population, mass urbanization, and so on. More than ever we need a science of design−a rigorous and systematic understanding of how to design.

A science of design promises to be domain-agnostic. That is, the idea of a science of design is that, apart from the domain specific expertise of rockets, hearing-aids, anti-retroviral drugs, or public policy, there is also knowledge and expertise in 'how to design' that we can bring to bear on each domain. As we mentioned above, this idea has met with some skepticism in the design, engineering, and scientific communities. And to be honest, so far it has not borne the fruit that we optimistically hoped for in the early days of the field.

I have argued that the way to a science of design −a thorough and systematic understanding of the processes to reach desired outcomes−lies in the approach of computational thinking. Over the past decades, computer-aided design has become widely practiced in every design domain−from architecture, to industrial design, to electronics engineering. The most important contributions of computer-aided design have not been in more realistic renderings or performance simulations. Certainly, these have been valuable. But the real contribution has been to offer computation as a way of conceiving design, as a medium for expressing and exploring design ideas. Computational representations − not only of the form of things, but also of their interactive behavior−are a powerful way to represent designs and design processes. That is why I believe that if we are to have a science of design, it will likely be computationally expressed.

I argued also that the technological changes in our world today are already moving us toward a profoundly computational view of designing. In this world, the designer's role will not be merely to make objects for people, but to describe design spaces and the rules that bound them, in ways that will enable citizens to design their own things, and that will provide "programmable matter" with dynamic and responsive behavior.

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Design Creativity : Integration of Design Insight and Design Outsight

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Abstract

The objective of this paper is to capture the essence of *design creativity* by focusing on *design insight* and *design outsight.* In this paper, it is shown that *design insight* and *design outsight* consist of two viewpoints : *criteria* and *motive.* Based on the reviews and discussions on *design insight* and *design outsight,* the design process is classified into three categories : *artistic design process, creative design process* and *systematic design process.* We define a combination of the *artistic design process* and *systematic design process* as the *creative design process,* and the nature of this process as *design creativity.* Finally, it is concluded that *design creativity* involves the integration of *design insight* and *design outsight.*

1. Introduction

Currently, design researchers are displaying a high level of interest in creativity. A large number of remarkable studies have been conducted, recently and various arguments with regard to creativity in the design process have been presented, for instance, research on the meta−cognitive level of design knowledge among people or research in the context of designers' behavior [1, 2]. To understand creative design knowledge, which is complex and involves multiplicity, research approaches that adopt advanced computational modelling [3, 4, 5] and those that involve a formal representation of design concepts based on the ontology theory [6] have been utilized. Moreover, a theoretical approach to the features of design strategy has been adopted on the basis of the relationships between concept and knowledge [7] ; this approach has demonstrated a framework for innovation from the perspective of knowledge creation. Moreover, several notable investigations on design cognition have been reported using analytical approaches targeting the important factors or conditions for the high creativity of expert designers [8, 9, 10, 11]. Furthermore, research methods have been obtained for establishing the means of supporting creativity in design [12, 13]. Thus, the trend of conducting research on creativity in the design process has become increasingly prominent.

This paper attempts to capture the essence of *design creativity* from another viewpoint. We focus on the notion of *driving force* that nudges the design process. There may be two types of *driving forces* for the design process−*push type* and *pull type* (Fig.1.). The *pull type driving force* refers to the force wherein the design process is progressed (*pulled*) from outside by something like a goal, while the *push type driving force* refers to the force wherein the design process is progressed (*pushed*) from within the person, by something that is deeply rooted in the mind. In this paper, we define the former *driving force* as *design outsight* and the latter *driving force* as *design insight.*

We assume that *design insight* and *design outsight* can be viewed in terms of two viewpoints : *criteria* and *motive.*

Here, the outline of the framework of *design insight* and *design outsight* is described, while each item is explained in detail in the following sections.

The first viewpoint of *criteria* involves analyzing the nature of the design process on the basis of the principles that govern the evaluation of the design process. In order to capture the

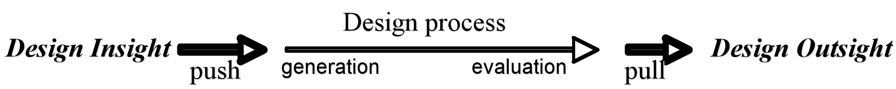


Fig.1. The notion of design insight and design outsight

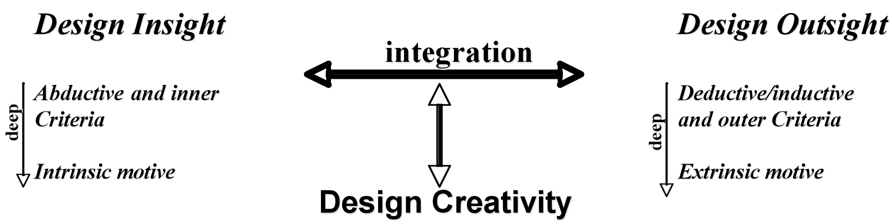


Fig.2. Framework of design insight and design outsight

essence of the *criteria,* we classify the *criteria* into three categories : *deductive, inductive and abductive.* Furthermore, from the viewpoint of systems theory, we classify the *criteria* into *inner criteria* and *outer criteria.* The *inner criteria* are related to the manner of viewing design in terms of *autopoiesis* (*self-creation* ; a term originally coined by Humberto Maturana) or *self-reference,* while *outer criteria* are related to the manner of viewing design in terms of *problem solving.* In the context of this paper, *abductive* and *inner criteria* are closely related to *design insight,* and *deductive/inductive* and *outer criteria* are closely related to *design outsight.*

The second viewpoint of *motive* involves discussing the nature of the design process on the basis of what impels it. *Motive* has been discussed by psychologists as an important factor for creativity. It has been reported that highly creative work is produced by those who have strong *intrinsic motivation* to engage in an activity [14, 15]. Therefore, whether the *motive* is *intrinsic* or *extrinsic* is a topic for discussion. Furthermore, whether an *intrinsic motive* is *coherent* or *noncoherent* is also discussed. It is suggested that an *incoherence-driven intrinsic motive* is related to *design insight* and an *extrinsic motive* is related to *design outsight.*

Further, the relationship between *criteria* and *motive* is explained as follows. *Motive* is thought to be more deeply rooted in the mind than *criteria.* Therefore, the relationship *criteria* –> *motive* has a layered structure and shows the degree of depth in the mind.

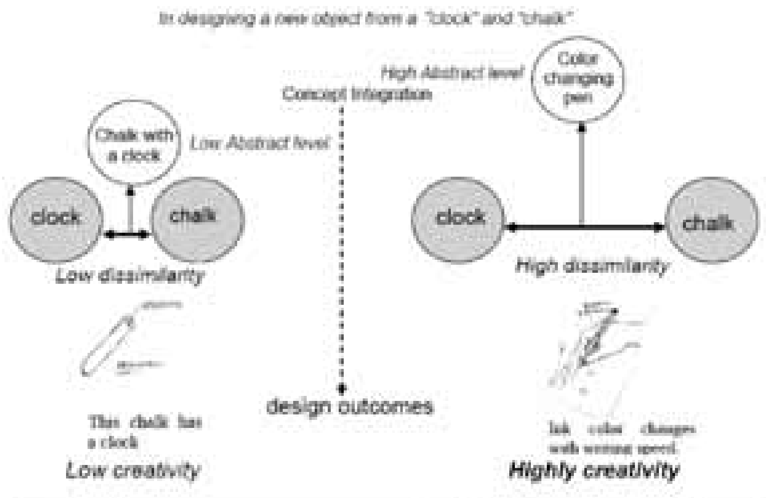
The above discussed framework is summarized in Fig.2.

Based on these discussions, we classify the design process into three categories : *artistic design process, creative design process* and *systematic design process,* and define *design creativity* as the nature of the *creative design process* in section 4.

Finally, it will be stressed that *design creativity* involves the integration of *design insight* and *design outsight.*

2. Criteria : The first viewpoint for design insight and design outsight

First, we describe the *criteria* in terms of categories : *deductive, inductive* and *abductive.*



Dissimilarity between concepts	Difficulty of design	Abstract level of concept integration	Creativity of design outcomes
Low	Low	Low	Low
High	High	High	High

Fig.3. Relationship between dissimilarity and creativity

Deductive criteria are determined according to certain deductive knowledge. As an example, let us consider the process of synthesizing two concepts. This process is the simplest and most essential process in formulating a new concept from the existing ones. With regard to the deductive knowledge on the concept−synthesizing process, we can show the knowledge that concerns the distance between the two concepts to be synthesized. That is, if the two concepts are very dissimilar, a highly creative design product may be obtained by synthesizing them [16]. Here, the term 'concept' is used to represent not only the image but also the object (natural and artifactual) being held in the mind. This knowledge was derived as follows. In the concept synthesizing process, a more creative new product can be produced when the notions, features and situations are combined at a more abstract level ; this abstraction is caused by the dissimilarity between the two concepts (Fig.3.).

Inductive criteria are derived from experience. The following is an example : when a person designs a creative design product, he/she may have conducted the same or a similar design process in different situations.

On the other hand, *abductive criteria* focus on foreseeing the nature of the design process. During the design process, we often determine something that can be evaluated only after the design process has proceeded for a while [17]. Let us consider the example of the invention of the art knife—the first snap-off blade cutter (Fig.4.). The inspiration for this incredible idea came from the synthesis of two concepts—chocolate segments that can be broken off and sharp edges of broken glass [16]. Although this invention is rather attractive, the problem of focusing on the chocolate remains unsolved. In other words, why is the chocolate focused on? Generally, chocolate is not associated with a knife. As shown in this example, it is extremely difficult to select the concepts to be synthesized before designing because the concepts that are required to produce a new creative concept can be evaluated only after they have been synthesized and the creative concept has been judged.

Further, *abductive criteria* are expected to be the most closely related to *design insight,* since abductive criteria are difficult to recognize explicitly and are thought to be deeply rooted in the mind of the designer, while *deductive criteria* and *inductive criteria* are more explicitly available, being governed by factors in the external environment of the designer.

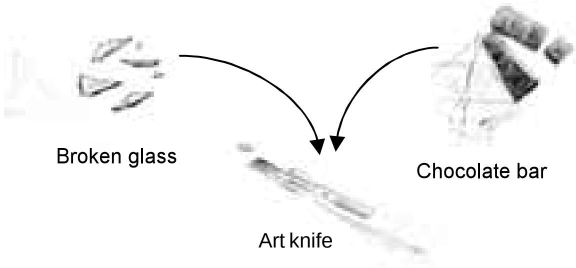


Fig.4. Design idea for an art knife by combining two concepts−glass and chocolate

On the other hand, from the viewpoint of systems theory, *criteria* can be divided into *inner criteria* and *outer criteria. Inner criteria* refer to the viewing of design in terms of *autopoiesis* or *self-reference,* while *outer criteria* refers to the viewing of design in terms of *problem solving.* Whether the *criteria* are *inner* or *outer* depends on whether or not the *criteria* are dependent on the design process itself. That is, if the *criteria* change during the design process only according to the design process and the design product, then the process is regarded as one that involves *inner criteria.* On the other hand, if the *criteria* can either remain unchanged or change according to the *outer* information, the process is regarded as one that involves *outer criteria.*

In general, the creative work of artists can be expressed as *autopoiesis* because the interaction between an artist and his/her works is continuously regenerated. Winograd and Flores (1986) called this process 'instructive interaction' [18]. From the viewpoint of personal creativity, knowing or learning a process by changing views through experience is also addressed as the continuous recognition process [19, 20]. During learning, the boundary conditions can be recognized as becoming increasingly wider based on inner views ; this was reported as an 'interactive redesign process' [21]. In general, creativity is also considered to be related to *self-reference* or *self-recognition* [22, 23]. Such an individual creative/learning process and organization can be explained as a structure-determined system [18]. Since Winograd addressed design as an issue related to an 'interaction process of understanding and creation' from wider social views, the function of information/communication design can be considered as the creation of a new experience [24]. It is necessary that these processes be experienced, which can be achieved only through inner views. Therefore, the *inner criteria* have been considered to be integral to *design insight* ; however, the objectification of the *inner criteria* is considered to be difficult.

Tab.1. Classification of the types of design processes

	Criteria (1)	Criteria (2)	Motive
Class 1 : Artistic design process	Abductive	Inner	Intrinsic
Class 2 : Creative design process	Abductive & Deductive/Inductive	Inner & Outer	Intrinsic
Class 3 : Systematic design process	Deductive/Inductive	Outer	Extrinsic

In contrast, the *problem solving process* is also used to represent the design process. There is one famous reference for the design process in engineering, which was originally represented as a model by Asimow (1962) [25]. Subsequently, interest in design methodology was activated in the 1960 s. This perspective is similar to the viewpoint of a *problem solving* process, in that they are both goal-oriented. In both the design processes, the objective views are suited to represent productive processes. Since Jones (1984) illustrated the design process as a three-step model (analysis-synthesis-evaluation) [26], it (design process) has been considered to have a sequential circulation structure [27, 28].

3. Motive : The second viewpoint for design insight and design outsight

In order to capture the very essence of *design insight* and *design outsight,* it is necessary to focus on the *motive* that is more deeply rooted than the *criteria. Motive* has been discussed by psychologists as an important factor for creativity. It has been reported that highly creative work is produced by those who have strong *intrinsic* motivation to engage in an activity [14, 15]. Whether a *motive* is *intrinsic* or *extrinsic* is a topic of discussion. An *extrinsic motive* is a stimulus from the outside (i.e. from an external source, e.g., a reward), which leads to humans channeling all their activities toward a particular goal. An *intrinsic motive* is an *inner motive* (i.e. from an internal source) that is responsible for human (personal) behavior, spanning from the bionic level, for example, ‘hunger’, to a higher cognitive level, for example, an artist’s ‘flow’ (a state of concentration or complete absorption with the activity at hand and the situation) [29]. The function of *intrinsic* and *extrinsic* motivation involves a reciprocal action in individuals. The *intrinsic motive* is thought to play an important role in *design insight.*

Whether an *intrinsic motive* is *coherent* or *noncoherent* can be another topic in the discussion on *intrinsic motive.*

Conceptual *coherence* has been explained by using connectionist models such as impression formation of people (IMP), and it is classified into two types : *coherence driven* and *incoherence driven,* by Thagard [30]. Based on the assumption that every concept possesses a network of associated concepts, abstract relations and constraints, an attempt can be made toward determining the relationships among the associated concepts, which then form the knowledge of the world (as in the case of IMP). Then, the problem of ‘how people select the appropriate relations in framing conceptual combinations’ can be expressed using a *coherence*-based computational model. It can be said that the selection of the relation of the connection itself is a *driving force* behind the formation of networks, that is, the *coherence-driven* process.

However, ‘*incoherence-driven* conceptual combination’ is distinguished from ‘*coherence-driven* conceptual combination’, from the perspective of creativity. As pointed out by Thagard, creative thoughts such as *abductive inferences* occur when a solution to a mundane problem cannot be obtained ; they leap beyond the *coherence-driven* process and necessitate constraint-satisfying reconciliation. Thagard suggested that the high potential of *incoherence-driven* creativity is ‘beyond’ the *coherence-driven* process.

4. Discussion on the essence of design creativity

Based on the above discussions, we characterize *design insight* as that which *pushes* the design process, particularly by *abductive* and *inner criteria* and *intrinsic motive.* On the other hand, we characterize *design outsight* as that which *pulls* the design process, particularly by *deductive/inductive* and *outer criteria* and *extrinsic motive.*

Furthermore, we classify the design process into the following three categories (Tab.1).

The *artistic design process* refers to the viewing of design as an art, and it focuses on representing the artist’s inner feelings. The *artistic design process* is impelled by the *push type driving force* and closely related to *design insight.*

The *systematic design process* is a type of *problem solving* process in which a problem is solved by the *pull type driving force* , which stems from the external environment of the designer. The *systematic design process* is closely related to *design outsight.*

The *creative design process* is a combination of the *artistic design process* and *systematic design process.* Design is a social activity ; it is not only related to the user but is also associated with culture or society. Moreover, it is important to represent the designer's inner feelings. Therefore, an ideal design process is one that not only involves representing the designer's inner feelings but also fulfilling the user's request or satisfying the demands of society. We define this design process as the *creative design process* and the nature of this process as *design creativity.* Its important function is that it should change the viewpoint of the *outer* and *inner criteria* and the viewpoint of the *abductive* and *deductive criteria* while internalizing the *extrinsic motive* into an *intrinsic motive.* Generally, creativity in design is considered to be evaluated by originality (novelty) and practicality (utility) [31]. Regarding the creativity in design, based on the above discussion in this paper, we would like to stress that the 'novelty' dose not involve the notion of 'strangeness' ; rather, it should be one that resonates with that which comes from the integration of *design insight* and *design outsight.* From this viewpoint, we define the *design creativity* as the integration of *design insight* and *design outsight.* We believe that this integration is difficult, and a key element of *design creativity* lies in this difficulty.

We show an example of the integration of *design insight* and *design outsight*. 'You-an' is a Japanese harmonious space (Fig.5.) [32]. This space is set up with light and water. Within the space, organic electroluminescent lights provide an 'organic glow' which has a flickering rhythm similar to that of a firefly from the natural world. This organic glow provides the impression of the earth's breathing. The idea of this space was adopted from a traditional tea ceremony room for entertaining guests. The designers of this space recalled memories of 'time' they spent in fields and activated their *inner feeling* from their *design insight.* Moreover, their design outsight was an aim to produce a healthy space with a gentle encompassing atmosphere for people. Lastly, the space You-an changed people's perception of the lights from one that is physical to one that is spiritual and evokes the impression of the nature.

5. Conclusion

In this paper, we focused on *design insight* and *design outsight,* and attempted to systematize them. As a result, we were able to illustrate that *design insight* and *design outsight* consist of two viewpoints : *criteria* and *motive.*

Based on these discussions, we could classify the design process into three categories : *artistic design process, creative design process* and *systematic design process.* We defined a combination of the *artistic design process* and *systematic design process* as the *creative design process,* and the nature of this process as *design creativity.* Finally, it is concluded that *design creativity* involves the integration of *design insight* and *design outsight.*

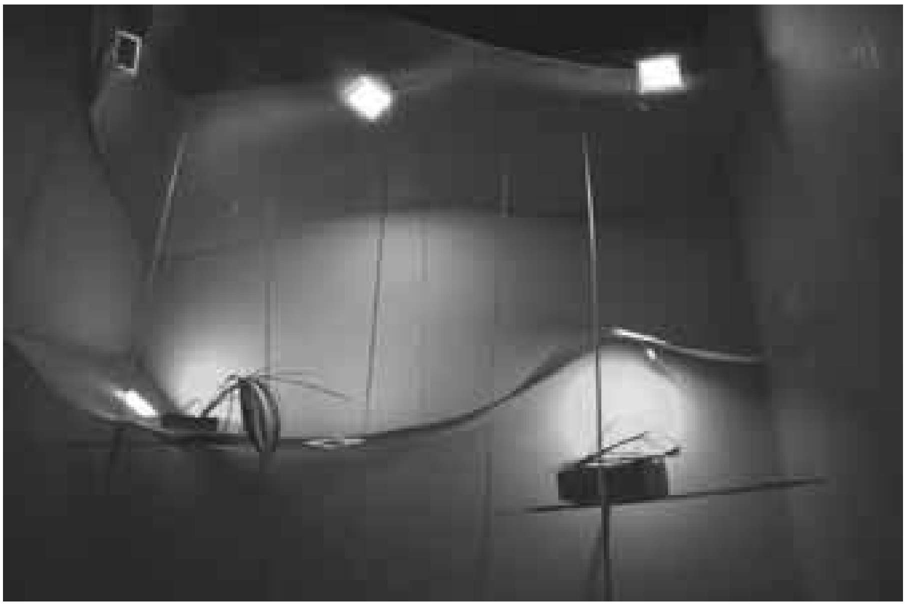


Fig. 5. Organic electroluminescence space You-an

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Heart of Impressions

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Abstract

This article introduces an analysis of deep impressions of artifacts, in order to gain a fundamental understanding about the design. Some researchers have discussed deeper impressions, which do not appear on the surface of impressions explicitly expressed by users. In this study, we advance the discussion on this kind of deeper impression, which we called the "Heart of Impressions." Concretely, we first discuss "where in people's mind can we capture the Heart of Impressions?" Next, we discuss "How can we capture the impressions?" under our hypothesis that "Heart of Impressions exists in the center of the structure, which involves not only the surface impressions but also the latent impressions." Then, we show a method for approaching Heart of Impressions by focusing on structure and the semantic network.

1. Introduction

Designers have to create products that fit the user's feelings, that is, ones that make good impressions on many people. Therefore, user's impressions on product design are sought to assist with the design of "good" products. In this article, we focus on impressions that are useful for designing "truly good" products and call them the Heart of Impressions.

1. 1. Shallow Impressions and Deep Impressions

After the Semantic Differential (SD) method was proposed by Osgood et al. [1], it has been applied for various products in various areas. This method focuses on measuring a user's impression of products quantitively and solving the difficultly of expressing the user's impression of a designed product by giving users some words and scales on the answer form. However, there are problems. It is necessary to decide the evaluation items beforehand. These are pairs of antonymic adjectives or nouns : for example, bright and dark, and the scales go from 1 to 5 or 7. In addition, in order to explain the collected result, the evaluation data are finally interpreted by humans. Additionally, the SD method is persistently a method of measuring the difference in the impressions that some products made on some people and the results cannot be evaluated without the products or people that were compared. Therefore, it seems to present a surface analysis of the impression and we call the impression analyzed by this method a "shallow impression." Although some methods are proposed based on fuzzy theory such as rough sets [2, 3] to evaluate collected impressions by using flexible integration, they are unable to capture more complete or deeper impressions.

On the other hand, we have a good example for the discussion about "deep" impressions. At the 2008 Design Symposium [4], one of the invited speakers, a product designer, Naoto Fukazawa said, "I always consider creating the products the user really wanted, although the users cannot express or tell what they want." Furthermore, he said, "I have tried to find the 'archetype' which represents the fundamental relation between the product and human."

The Greek philosopher Plato originally formulated the archetypes. Later, in psychology, Jung called the contents of the collective unconscious, which are in the bottom of unconsciousness, "archetypes," and mentioned that an archetype is an unlearned tendency to experience things in a certain way and has no form of its own, but it acts as an "organizing principle" for the things we see or do [5]. In other words, it is the ancient, unconscious source for human beings, that is, a universal and common form of the pattern or image of the human race. This is the concept of psychological archetypes, and popular archetypes. In the present day, archetype is generally defined as an original model of a person, object, or concept from which similar instances are derived, copied, patterned, or emulated. This definition of archetype would apply to what Fukasawa said.

He also said, "we need not design only an novel product but should design a simple one." We think an idea of simple product is closely related with the user's deep impressions.

1. 2. Primitive Sensitivities

Cognitive semantics studies in linguistics have analyzed the generation process of languages. From the perspective of understanding conceptual abstraction, they have discussed the structured metaphors in a deep part as "image schema" [6, 7]. An image schema represents a reappraisal of metaphors that is the human embodiment of language through life. These understandings of metaphors indicated new methods of interface design by using representations based on the simple way of the metaphoric visual system (i.e. "right hand side" means the better direction). However, the image schema depends on the phenomena of physics and particularly focuses on physical situations. We consider that image schema may potentially enhance design effects, although it would be too deep to be useful for designing artifacts.

2. How can we capture the Heart of Impressions?

How can we capture the Heart of Impressions? We focus on two viewpoints. The first is the "structure of impressions" that assumes the Heart of Impressions is more than the sum of the partial impressions, and the second one is "latent impressions" that underlie the surface impressions.

2.1. Structure of Impressions

Aristotle said, "The whole is more than the sum of its parts." This has been well known in various science fields for its complexity and is called "holism" [8]. There exists "something" appearing as the whole. This phenomenon has been put forward as "emergence" by Polanyi [9], who said, after mentioning human knowledge, "We can know more than we can tell" and "the question much discussed by philosophers of how we can infer the existence of other minds from observing their external workings does not arise, for we never do observe these workings in themselves." These quotations suggest that we should dwell in a whole to understand the whole, that is, to probe the "something" in the whole. Then, to capture a user's impressions, we should attempt to dwell in a whole by using the parts of the whole as clues, without only analyzing each part.

How do we dwell in an impression? What is the impression? As one answer, we focus on constructing the structure based on these impression words and think that the structure can play the role of the whole impression that leads to the Heart of Impressions.

In the field of design studies, some researchers have focused on the notion of structure. Goldschmidt introduced "linkography," which is a method that proposed using protocol analysis for examining the design productivity of designers [10]. This can show the structure of a designer's thinking very well. However, linkography is defined by what each designer has. Therefore, it cannot be used commonly in design : that is to say, designers from different backgrounds might produce a different linkograph from the same protocol. Georgiev et al. proposed a design method by focusing on the structured meanings that are constructed among multiple impression words [11]. Their method is based on the analysis of logo designs using semantics analysis [12]. They analyzed the meanings of one design example by the sum of relatedness between the impression word and an associated word. Their analysis has developed into another design evaluation method that focuses on the depth of emotional impressions [13]. Harakawa et al. [14] have clarified that there is a strong relationship between the extension of thinking space during designing and higher creativity in the design ideas created by concept synthesizing process, in which design ideas are created from two given concepts. The extension is defined based on the distance between explicit concepts in the protocol expressing the thinking space, and corresponds to a feature of the structure of the thinking space during designing.

These studies indicate the structure of impressions may be related to deep impressions.

2. 2. Latent impressions

We believe that humans cannot express all impressions explicitly. Some studies have discussed this matter, referring to the notion of "latency." Latent sensitivities are rising up in many fields of design.

As an example, there is a study that focused attention on the idea of "latent function," to construct a design methodology for artifacts suitable for an environmentally conscious society [15]. Latent function [16] means the total behaviors of the entity that can be observed for any circumstance : that is to say, although the entity has a peculiar behavior that manifests itself as correspondent to a certain circumstance (referred to as visible function), different behaviors are observed for different circumstances. The total of these behaviors is called latent function.

Also, Dong proposed a latent semantic approach to studying design team communication [12]. Latent semantic analysis [17] is a theory and method for extracting and representing the contextual-usage meaning of words by statistical computations applied to a large corpus of text, in natural language processing, and, in particular, vectoral semantic. He showed empirically that the similarity of language use bridges the indirect relations among components of knowledge stored in each designer's mind and that latent semantic analysis can model the "psychological similarity between thoughts" based on language.

These researches indicate that latent sensitivities can be used to extract functions or relations that cannot be expressed explicitly.

As an example for emotion, in order to capture customer's latent need, a method for shape generation by showing unexpected viewpoints was proposed by Yanagisawa [18], focusing on the fact that customers have a latent sensitivity of which they are unaware.

In this paper, we call this deeper impression, which does not appear on the surface of impressions explicitly expressed by users, "Heart of Impressions." Therefore, we may be able to capture the Heart of Impressions by extracting the latent impressions that underlie the surface impressions.

3. Approach to Heart of Impressions

3.1. Hypothesis

Based on the above discussions, we set up the following hypothesis.

- The "Heart of Impressions" exists in the center of the network structure, which involves not only the surface impressions but also the latent impressions.

Fig.1. shows the images for our hypothesis. White circles are nodes corresponding to explicit impression words. Circles colored in gray or black are latent impression words. Black circles are nodes in the center of the structure of the network that express the Heart of Impressions.

In this article, "explicit impression word" implies a word explicitly expressed by humans on an artifact, while "latent impression word" implies the concepts that are thought to underlie the explicit impression word.

Fig.1. Image of existence of Heart of Impressions in the impression network

3.2. Virtual Impression Network using Semantic Network

We propose a "virtual impression network structure" which involves the notions of "structure" and "latent impressions" by using the semantic network.

The network construction processes are shown below.

Step 1 : Extracting paths between two explicit impression words in the semantic network. Here, a path is a set of links joining directly between a word and the next word. The words that are found along each path are regarded as latent impression words.

Step 2 : Collecting words appearing in the extracted paths, that is, explicit impression words and latent impression words.

Step 3 : Drawing the network having the collected words as nodes and the links comprising the extracted paths as edges.

Semantic networks have a word meaning as a node. Therefore, we searched out the shortest path between meanings of explicit impression words and extracted the latent impression words in the path between the explicit impression words. Fig.2. shows an image of searching out a path in a semantic network. Circles are nodes in the semantic network. White ones are nodes for explicit impression words. Gray ones are latent impression words appearing on the path between the nodes of the explicit impression words. Arrows are the links comprising the path. The middle figure in Fig.1. shows an image of a virtual impression network having these kinds of nodes.

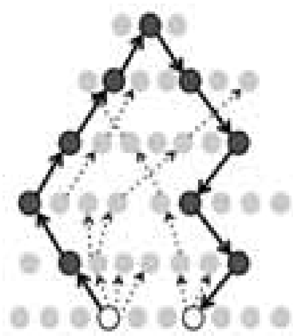

Fig.2. Image of searching out a path between impression words.

3.3. Network Centrality

As one approach to the Heart of Impressions, we focused on the centrality of the network structure and extracted the center of the constructed network as the approximate Heart of Impressions. It would seem to play a role of the Heart of Impressions.

Network centrality is an indication of what kind of node and link are important in the network. Three centralities, “degree,” “closeness,” and “betweenness,” are well known [19]. As a first step, we used degree centrality that is the simplest centrality. Degree centrality is a centrality measure for the number of links that a node has in its network. We extracted words having high centrality as the candidates for the Heart of Impressions. The words in its approximation are expected to be close to the user’s deep impression evaluation such as function, shape, and color.

Also, we think these words will be closer to the nature of the artifacts than the concept expressed by explicit impression words in the different dimension because most of them are latent impression words, that is, virtual (implicit) nodes extracted by using the semantic network. Moreover, extracting them would correspond to fundamentally observing artifacts, similar to what Fukazawa said. Fig.3. shows an image of the relationship between the explicit impression and the Heart of Impressions.

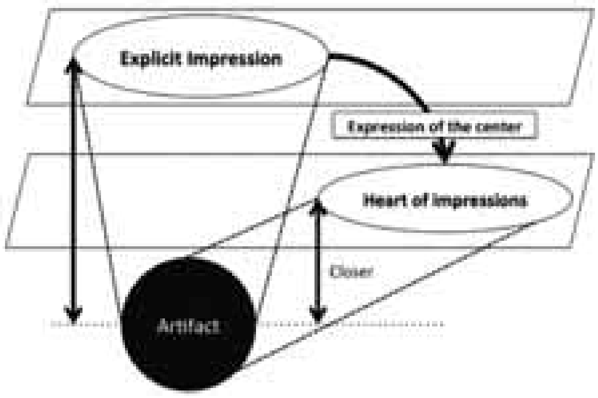

Fig.3. Image of positional relationship between explicit impression and Heart of Impressions.

4. Experiment

In this research, in order to verify our hypothesis, an experiment was conducted.

The subjects were asked to perform two kinds of tasks. One was to describe the impression by using some words, looking at a picture of each product. Another was to indicate the boundary of like and dislike for the products. All subjects were Japanese. Ten adult graduate students participated in this experiment and six cups were used for the experiment.

4. 1. Method

The method of the experiment is shown below.

Description of impression (2 minutes for each cup) :

The subject was shown a picture of each cup and asked to describe the impression using some words in Japanese, where noun, adjective, and verb were required to be set out in a separate column with at least one word for each category.

Indication of boundary :

The subject was asked to rank the six cups according to preference and draw a boundary of like and dislike.

4. 2. Results

Here, we show the results for one subject. The number of explicit impression words described by this participant for a cup like that shown in Fig.4. is 20. The impression words are as follows :

cup, weak, hold, winter, carry, sea, usage, difficult, small, saucer, spoon, cold, break, coffee, black tea, cake, weight, cleaning, fall, blue.

Fig.4. Drawing of a certain cup that was shown to the participants.

5. Analysis

5.1. Preprocess

WordNet 3.0 [20] was used as a semantic network to construct the virtual impression network structure. WordNet is a huge lexical database in English. However, there are only links between words belonging to the same POS (part of speech ; for example, noun-noun). Accordingly, we performed two preprocesses. First, we translated into English, while confirming that the meanings were consistent with the Japanese. Next, we replaced all verbs and adjectives by corresponding nouns. After this process, according to the network construction method explained in section 3.2, the virtual impression network was constructed.

5.2. Extraction of nodes with high centrality

As the approximate Heart of Impressions, we extracted the nodes with high centrality by using the network visualization and analysis tool Pajek [21]. Fig.5. shows the virtual impression network of a certain participant, that is, her impression of a cup design.

Fig. 5. Virtual impression network for a cup by a certain participant

In this analysis, nodes having more than 3 links were extracted as the approximate Heart of Impressions (hereinafter, called “central nouns”). The words were as following :

abstract entity, activity, change, nutrient, physical entity, property, substance, tableware, ware.

It can be recognized that there are not only high abstractive words but also relatively low abstractive words such as “tableware” and “change,” which are expected to be the approximate Heart of Impressions.

5.3. Comparison

In order to verify the possibility that the extracted words were the Heart of Impressions, we classified the explicit impression words and the central nouns of a cup obtained from each subject by using Multi Dimensional Scaling (MDS). Fig.6. shows the distribution based on the explicit impression words and Fig.7. shows that based on the central nouns. As a result, it is found that a boundary between subjects (whether they like the cup or not) can be recognized in Fig.7., while that cannot be recognized in Fig.6. This shows the central nouns may indicate the Heart of Impressions.

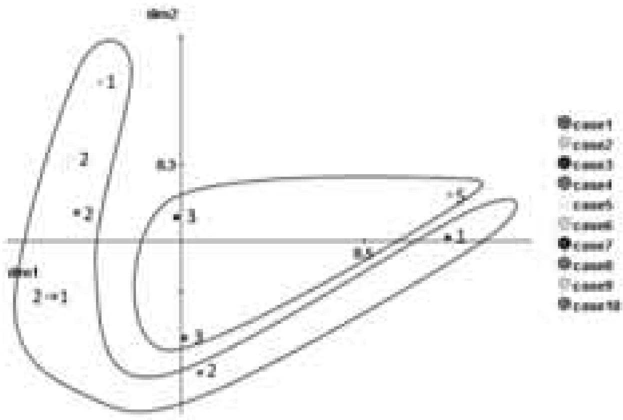

Fig.6. The distribution of participants based on impression words.

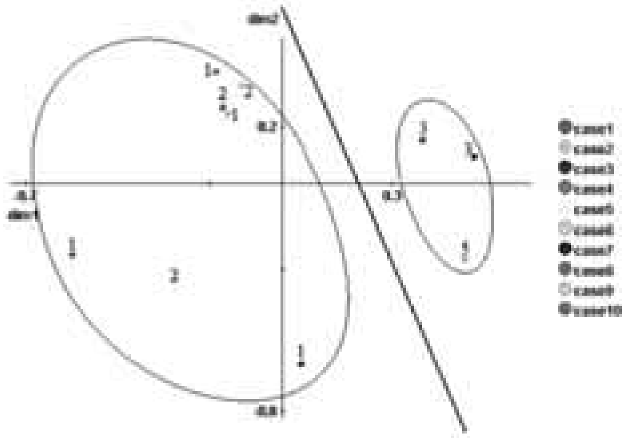

Fig.7. The distribution of participants based on central nouns.

6. Conclusion

We discussed the deeper impression of an artifact by calling this impression the Heart of Impressions. Concretely, we discussed two issues ; “where in people’s mind can we capture impression?” and “how can we capture the impression?” Regarding the first issue, we reviewed the studies on the SD method and image schema and pointed out the importance of deep impression in order to design a truly good product. Regarding the second issue, we focused on two viewpoints : structure of impressions and latent impressions. Based on the above discussions, we proposed a hypothesis that a “Heart of Impressions” exists in the center of the network structure that involves latent impressions as well as explicit impressions.

We developed a method for extracting the Heart of Impressions by using the semantic network. We performed an experiment and showed the possibility for this method to be an approach to finding the Heart of Impressions.

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Mark D GROSS

Mark D Gross is a professor of computational design at Carnegie Mellon University's School of Architecture. He first became entranced with a PDP-8 computer when he was a boy and learned to program by studying assembly language listings of compilers and interpreters written by virtuoso designer/ programmers at Digital Equipment Corporation (DEC). He became interested in artificial intelligence and cognitive science in the days when it was possible to read almost everything written on the subject.

Gross studied architectural design at MIT and graduated in 1978 with a Bachelor of Science degree. While a student he worked at the Architecture Machine Group, where he met design methodologist N. John Habraken, who later supervised his PhD work. However, before entering the PhD program in architecture, Gross worked as a programmer at the MIT Logo Laboratory on a version of the Logo programming language for children, and then at Atari Corporation's Cambridge research lab. In 1986 he completed his PhD in design theory and methods at MIT, working with Professors Habraken and Aaron Fleisher ; the title of his dissertation is "design as exploring constraints". In 1990 Gross began teaching at the University of Colorado, Boulder and in 1999 he moved to the University of Washington, Seattle. There, with Ellen Yi-Luen Do he founded the Design Machine Group, a design computing research laboratory. In 2004 he joined the faculty of the School of Architecture at Carnegie Mellon where he currently supervises PhD students in computational design and directs a Master program in Tangible Interaction Design. He has published over 100 peer-reviewed and invited articles on design and computing topics.

Mark D Gross worked on a constraint model of−and a programming language for− design ; on diagram and sketch recognition ; and tangible user interfaces. In recent work on computationally enhanced construction kits and craft, his students have built prototypes of innovative constructionist toys. Based on this research, Gross recently co-founded roBlocks LLC, a company to manufacture and distribute a modular robot construction kit toy for children to experiment with emergent behavior and robot design. Fundamental to all his work is a commitment to empowering end-users to design and extend their own environments ; this is a theme common to the architectural design methods of Habraken and the children's programming language Logo. Gross sees pro.gramm.ing and de.sign as much the same, and notes that the roots of the two English words are closely related, and he cannot understand why the rest of the world insists on boundaries between domains.

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