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REQUIREMENTS AND THEORIES OF MEANING

Ichiro Nagasaka
Kobe University

ABSTRACT

In this paper, the fundamental characteristics of the concept of meaning in the traditional theory of design are discussed and the similarities between the traditional theory of design and the truth-conditional theory of meaning are pointed out. The difficulties brought by the interpretation of the model are explained in the context of theory of design and the argument that the sequence-of-use based proof-conditional theory of meaning could resolve the difficulties by changing the notion of the requirement is presented. Finally, based on the ideas of the proof-conditional theory of meaning we show the perspective of the formulation of the sequence-of-use based theory and discuss how the theory deals with the sequence of use in a constructive way.

Keywords: Requirements, theories of meaning, constructive theory of design

1 INTRODUCTION

As we all know, the requirement or the need has an essential role to play in the process of design. Most of the theories of design proposed since the early 1960s share the view on the requirement. For example:

- Design begins with the recognition of a need and the conception of an idea to satisfy this need [1, p.iii].
- The main task of engineers is to apply their scientific and engineering knowledge to the solution of technical problems, and then to optimize those solutions within the requirements and constraints [...] [2, p.1].
- It is widely recognized that any serious attempt to make the environment work, must begin with a statement of user needs. Christopher Jones calls them performance specifications; Bruce Archer calls them design goals; [...] they are often simply called 'requirement' or 'needs' [3, p.124].

The role of the requirement is analyzed further by Alexander in the following way [3, p.124]:

> Whatever word is used, the main idea is always this: before starting to design a building, the designer must define its purpose in detail. This detailed definition of purpose, goals, requirements, or needs can then be used as a checklist. A proposed design can be evaluated by checking it against the checklist.

In other words, it is assumed in these theories that designing can neither be started without knowing the requirements nor finished without satisfying them. Therefore, it is expected for every theory of design to have answers to the following two critical questions:

Q1: How can we know requirements?
Q2: When can we know they are satisfied?

The answers to the question may be categorized into two types. First are:

A1: By obtaining social and technological conditions to be fulfilled by artifacts.
A2: When the artifacts satisfies the conditions.

These are, of course, typical of traditional theories of design such as the theories mentioned earlier [1, 2, 4, 5]. The main characteristic here is that the requirements are satisfied by *artifacts*. Above quoted Alexander's words conveniently summarize this traditional view on the requirement.
Second are:

A1: By observing how people use artifacts.
A2: When people actually use the artifacts.

Theories of design with this view on the requirement, such as scenario-based design [6, 7], usually focus more on the action of user than artifacts that are the main concern of the traditional theories of design. In this case, the requirements are satisfied by people's actual *use*. These distinct attitudes toward the requirement reflect the fundamental difference of the way we understand design, especially in the notion of meaning of the artifact.

While studies for meanings of artifacts has been conducted from the late 1980s [8, 9, 10, 11] where various theories of meaning have been examined, theses studies are, in large part, based on semiotics or Gibson's ecological approach. On the other hand, in the area of philosophy of language and proof theory, the theory of meaning has also been extensively studied. In the theories of meaning, there has been the argument over how the meaning of a sentence is determined between two schools, namely, truth-conditional and proof-conditional theory of meaning [12]. As explained in the following section, there is a remarkable correspondence of the argument between these two schools with the distinct attitudes toward the requirements in the theories of design, e.g., existence of models and interpretation of them in the traditional theory of design and the truth-conditional theory of meaning, as opposed to the primary emphasis on sequence of use in the scenario-based design and the proof-conditional theory of meaning.

The aims of this paper are threefold. First of all, to discuss about one of the fundamental characteristics of the concept of meaning in the traditional theory of design, i.e., the existence of model, and to point out similarities between the traditional theory of design and the truth-conditional theory of meaning, then to show the difficulties brought by the interpretation of the model in the context of theory of design.

Second, to present the argument that to resolve the difficulties in the interpretation of the model in the traditional theory of design, it is necessary to make the shift from the model based truth-conditional theory of meaning to the sequence-of-use based proof-conditional theory of meaning by changing the concept of the requirement.

Third, to show the perspective of the formulation of sequence-of-use based theory called *constructive theory of design*. Here, the proof conditional theory of meaning will provide vital information. However, in order to apply the proof conditional theory of meaning to theory of design, modification of the concept of proof will be necessary since, as noted by Gedenryd [13], the proof itself is, in general, not regarded as the sequence of mathematicians' proof activities but as an syntactical object in mathematics.

2 TRUTH-CONDITIONAL THEORY OF DESIGN

Theories of design known as *design methodology* were proposed in the 1960s [1, 4, 5], and criticized by some of the same authors in the 1970s [14, 15]. In spite of these criticisms, the conception behind the methodologies, among which the most notable one is *analysis – synthesis – evaluation* process of design activity, still maintains significant influence on the subject [2, 16, 17]. To discuss about the nature of the traditional theory of design, especially how the meaning is treated in the theory, Alexander's "Note on the Synthesis of Form" [4] is taken as an instance, since his methodology is still very influential and was explicitly and formally constructed on the basis of the analysis – synthesis – evaluation framework.

2.1 Existence of Model and Its Interpretation in Design Methodologies

In "Note on the Synthesis of Form", Alexander showed figure 1 to explain the role of the designer in the process of design. In the figure, the context C1 and the form F1 are the real context of the actual world, i.e., the part of the actual world, and the physical form of an artifact in the context, and C2 and F2 are the mental picture of them in the designer's mind, respectively. C3 and F3 are the system of the formal picture of the mental pictures. Here, C3 is said to be described in the formal language of set theory. As a matter of course, his design methodology was developed in the formal picture, since the methodology itself has to be objective and public so that everyone can carry out.

Now, how do we know the meaning of the formal expressions of artifacts such as F3 in C3, or rather, what gives the meaning to F3 in C3? The answer is simply that we know the meaning through the interpretation of F1 in C1 by way of the mental picture F2 in C2. For example, in the formal system with

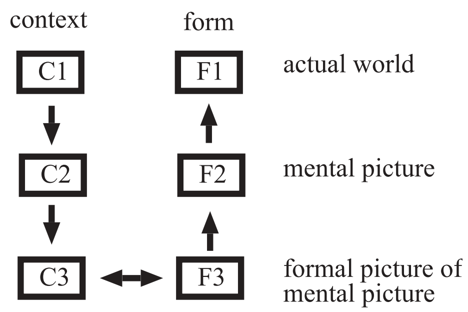

Figure 1. Context and form

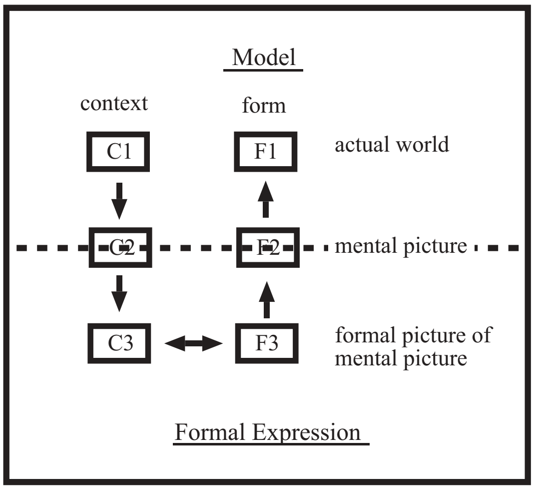

Figure 2. Model and expression

an identity symbol "=" such as the set theory, the simplest case would be that two element m_1 and m_2 are equal, i.e., "$m_1 = m_2$", where m_1 and m_2 are constant symbols, if $m_1^{C1} = m_2^{C1}$ is established within the context C1 of the actual world[1]. More precisely, the meaning of "$m_1 = m_2$" is given by a recursively specified group of interpretation functions from each part of the expression "$m_1 = m_2$" to the predefined domain C1. In mathematical logic, C1 is usually called *structure* or *interpretation* of C3, and as shown in the example, when a certain expression (e.g., "$m_1 = m_2$") in C3 is hold in the structure C1, C1 is called the *model* of the expression. In this way, the meaning of the formal expressions of artifact F3 is given by models in the traditional theory of design.

Contrary, if there is no structure or interpretation of the formal system, the expression of the formal system have no meaning, thus, does not make sense. There might be some traditional theories of design that seem to have no models on the surface, but there should be some models presupposed implicitly.

2.2 Abstract Model

In Alexander's methodology, the model was the actual world. But in many case, the models are made by some sorts of abstraction of (part of) the actual world. For example, 2D or 3D drawings, geometric models in CAD, preproduction sample or prototype, and simulation model could all be used as models in the theories. As a matter of fact, if the actual world is adopted as a model, it is rather difficult to give clear and objective judgment in an evaluation process of design, since the actual world can be interpreted in many ways depending on viewpoints. Therefore, to fix the interpretation, the model specific to the methodology would be abstracted from the actual world, and at the same time, the object domain of the

[1] m_1^{C1} stands for an interpretation of m_1 under an assignment function C1.

methodology is determined depending on it. In a design methodology for minimizing air resistance of car body, a model based on aeromechanics would be adopted and in a methodology for the structural design of buildings, a geometric models and prototype based on structural mechanics would be used.

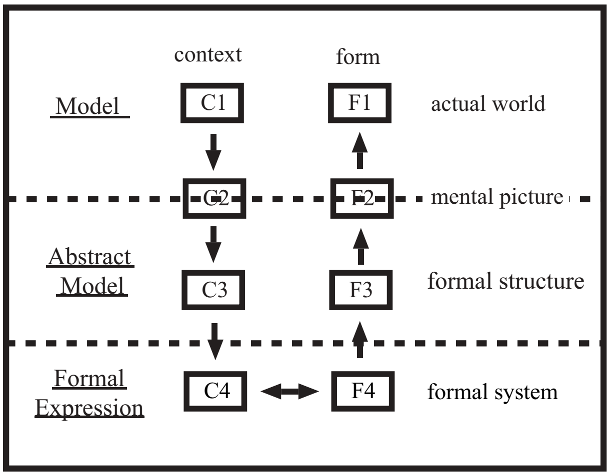

Figure 3. Formal system with abstract model

In the formal system of mathematics, it is commonplace to set up a structure using sets and give a semantics of the system by the structure. Even though it is not depicted in the figure 2, actually Alexander's theory is also based on the formal system in which the semantics is given by the abstract model formalized by set-theoretic constructs. To show this explicitly, the formal systems C4 (and of F4) where his methodology is formulated are added (figure 3). Thus, what it comes down to is the following:

C1, F1: a context, that is, a part of the actual world and a form in the context;
C2, F2: the mental picture of C1 and F1;
C3, F3: the formal expression of C1 and F1 by way of C2 and F2;
C4, F4: the formal system whose model is C3 and a formal expression F3 in the system.

Ideally, C3 is an "appropriate" description of C1, and an solution F3 is obtained without the process of analysis and synthesis. Then, F1 is constructed by the natural interpretation of F3. In this case, however, we don't need designers. So, in reality, C3 would be regarded as a tentative description of C1 and by doing analysis in C4 and synthesis on F4, F3 would be obtained by interpreting F4 into F3. If C3 is the model of C4 (this means C4 is consistent since C4 has at least one model), and the analysis – synthesis process is carried out consistently, F3 logically fits into C3 without the evaluation process. (This would be one of the reasons why there is no evaluation process in Alexander's methodology.) Then, we can complete the design process if F3 fits into C1 after the series of interpretations F3 $\rightarrow$ F2 and F2 $\rightarrow$ F1, and comparison between F1 and C1. If this series of interpretations are also "appropriate", F1 should be fit into C1, because C3 and C4 are supposed to be the consistent formal structure, and the analysis – synthesis process is supposed to be logically consistent procedures. But this is unlikely in reality. Thus, when F3 doesn't fit into C1, another tentative formal structure C3' would be constructed and the analysis in C4' and synthesis on F4' will be carried out again. Then the series of interpretations will take place and F1' will be evaluated in C1, again. This cycle will continue until a solution in the formal structure fits into C1.

2.3 Correspondence between Traditional Theory of Design and Truth-Conditional Theory of Meaning

The most significant characteristic of a truth-conditional theory of meaning is that it is based on a theory of truth in Tarski's style. Tarski showed in [18] that, for a given formal language L, how to define a predicate ‘$\text{True}_L(x)$’ such that for every sentence S of L it is provable from the definition that

$$\text{True}_L(\bar{S}) \text{ if and only if } f(S). \tag{1}$$

Here, ‘$\bar{S}$’ is a *name* of, and $f(S)$ a *interpretation* of, the object-language sentence S in the language of the meta-theory[2]. Using the concept of meaning (in the guise of ‘translation’ from object-language to meta-language) Tarski gave a precise definition of what it is for a sentence of L to be true [12].
It seems obvious that there is clear correspondence between how we know the meaning in the traditional theory of design and the truth-conditional theory of meaning. The relationship between meta- and object- is relative concept, thus, with regard to the relationship between C3 and C4, the object-language is the formal system C4 and the meta-language is the C3, and with regard to the relationship between C1 and C3, the the object-language is C3 and the meta-language is C1. Using of the concept of meaning in the guise of interpretation from C4 to C3 (or C3 to C1), we could know what is it for a form F4 of C4 (or a form F3 of C3) to be fitted.

2.4 The Roles of the Model in the Design Methodology

The primary role of the model in the theory of design is, as mentioned earlier, to give a domain through which certain interpretation to the expressions appearing in the theory can be given. Then, what is the motivation for establishing the interpretation? In mathematics, there can be several reasons, but the primal reasons would be to know if the formal system is consistent and to know the validity of theoretical reasoning within an idealized logical structure. In the theory of design, these could also be significant reasons, however, there seems to be the prior motivation, that is, to answer the above stated two critical questions:

Q1: How can we know requirements?

Q2: When can we know they are satisfied?

To answer Q1 in the traditional theory of design, we have to obtain social and technological conditions to be fulfilled by artifacts. In order to obtain the requirements, the model and its interpretation seems essential.
As in figure 3, a designer constructs abstract model C3 according to one’s interpretation of C1 that provides the real social and technological requirements in the actual world. Based on C3, the designer analyze the requirements in the formal system C4. In the case of the example, i.e., kettle, shown by Alexander in his book, the requirements are about production, safety, use, capital and maintenance (figure 4).

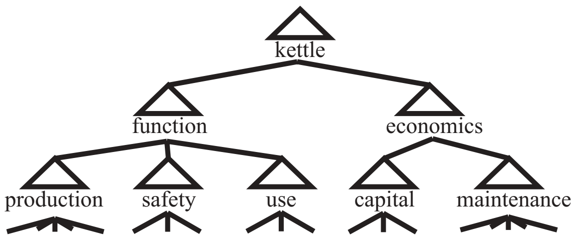

Figure 4. Requirements for kettle

According to the analysis, the designer constructs the expression of artifact F4 through the process of the synthesis, and then, evaluates if F4 satisfies the requirements in C4. If F4 satisfies them, after the interpretations F4 → F3 (→ F2) → F1 the artifact F1 (a kettle) is produced in the actual world based on the expression. Finally, F1 is evaluated in the context C1 of the actual world. The analysis process consists of procedures C1 (→ C2) → C3 → C4 is the process of *knowing requirements* and the synthesis

[2] The meta-theory in which the truth definition is given and where all instance of (1) must hold.

process consists of F4 → F3 (→ F2) → F1 is the process of *knowing the satisfaction of requirements*. In this manner, the model and its interpretation has the critical roles in answering the critical questions, and it seems clear that the analysis – synthesis – evaluation framework is founded on the existence of the model.

2.5 Difficulties Concerning the Model

In this sort of traditional theory of design, there seems to be some fundamental difficulties to be pointed out. The abstract model C3 is constructed from designers' points of view. Therefore, even if F3 fits into C3, it only shows that F1 can be constructed in the context set by the designer-made abstract model C3. Similarly, the requirements analyzed in the formal system C4 also depends on the abstract model C3, therefore, it is uncertain that the requirements is "really" abstracted from the context of the actual world. To put it simply, every meaning in the theory of design depends on the designer's interpretation of the model[3]. Everybody else cannot be sure that the interpretation is "appropriate", and the needs are reflected "appropriately" in the model.

On the other hand, there has been much criticism concerning logical consistency of the process of analysis, synthesis and evaluation process in design. One of them is that the design activity is, unlike the activity of mathematical proof, not logically consistent activity. Another is that design is the ill-structured problem, that is, its initial specification is usually incomplete; the initial vagueness prevents the designers from constructing a precise problem solving space and setting clear criteria for determination of a solution [19]. Both of them are closely related to the difficulties concerning the interpretation of the model. If the design activity is logically inconsistent, it cannot have any consistent abstract model, thus, the appropriate interpretation of the model simply does not exist. And, the indefinite interpretation of the model yields the indefinite abstract model and causes the incomplete initial specification. As a result, design becomes an ill-structured problem.

3 WHAT IS A REQUIREMENT?

Why can't we be sure about the appropriateness of the construction and the interpretation of the model? As mentioned earlier, to answer the question "How can we know requirements?", the model and its interpretation seems essential. However, there is implicit assumption here, that is, we naturally know the concept of the requirement (need). Alexander and Poyner [3] pointed out against exactly this assumption:

> But how do we decide that something really is a need? The simplest answer, obviously, is 'Ask the client'. Find out what people need by asking them. But people are notoriously unable to assess their own needs. Suppose then, that we try to assess people's needs by watching them. We still cannot be sure we know what people really need. We cannot decide what is 'really' needed, either by asking questions, or by outside observation, *because the concept of need is not well defined* (emphasis author's).

If we had the clear definition of the concept of requirement, everybody could see whether the designer's construction and interpretation of the model is appropriate with regard to the requirement. But we are not sure what the requirement is. Thus, if what Alexander and Poyner stated is true, the fundamental difficulty of the traditional theory of design cannot be resolved. Then, they proposed to replace of the idea of requirement (need):

> We shall, therefore, replace the idea of need, by the idea of 'what people are trying to do'. We shall, in effect, accept something as a need if we can show that the people concerned, *when given the opportunity*, actively try to satisfy the need. This implies that every need, if valid, is an active force. We call this active force which underlies the need, a *tendency* (emphasis author's).

[3] In mathematics, the validity of a sentence also depends on the interpretation of the model. Even when the model and the sentences are fixed, the validity alters with regard to the interpretation function from the formal system to the model.

After the idea of requirement is defined in this way, the idea becomes testable. Therefore, it is not necessary to interpret the actual world and construct the abstract model to know the requirement. Instead, we just have to observe whether people actively try to fulfill the given opportunity in the real world. Consequently, the problem concerning the construction and interpretation of the model disappears.
When we think of the requirement as “what people are trying to do”, the requirements are satisfied by people’s actual activity, that is *use*. In software engineering [20, 21, 6] and other domains [22, 23, 24], there has been increasing interests in designing people’s use itself in the form of *scenarios*. This attitude toward use in the scenario-based design has a lot in common with the proof-conditional theory of meaning. This common ground is clearly expressed by Martin-Löf [25]:

> A proof is, not an object, but an act.

In this view, mathematics is regarded not as system of concept but as system of action.

4 PROOF-CONDITIONAL THEORY OF MEANING

Dummett has presented his argument against the truth-conditional theory of meaning in many places, i.e., [26, 27, 28]. I will not go into the details of his argument. For the moment, it should suffice to offer some of his arguments from [28].

> It is true that there is no single universal any unmistakable sign of acknowledgment of the truth of a given sentence, nor any absolutely standard means of eliciting such a signal: but it is reasonable enough to suppose that [...] we can devise a criterion for a speaker’s recognition of the fulfillment of the condition which establishes any given sentence as true.
>
> Many features of natural language contribute to the formation of sentences not in principle decidable: the use of quantification over an infinite or unsurveyable domain; the use of the subjunctive conditional, or of expressions explainable only by means of it; the possibility of referring to regions of space-time in principle inaccessible to us.

That is, the bivalent truth conditions are sometime undecidable and accordingly beyond our capacity of recognition. But the central concept of a theory of meaning must be effectively decidable. Thus, the truth-conditional theory of meaning cannot be a plausible theory of meaning. Then, he said, a theory of meaning in terms of verification, i.e., proof-conditional theory of meaning, would be an acceptable theory of meaning[4].
In [29], Prawitz tentatively summarized Dummett’s formulation of the proof-conditional theory of meaning in [26]. Firstly, he showed the principle that *meaning is determined by use*:

> The basic idea on which the semantical argument rests is expressed in the principle that the meaning of a sentence is exhaustively determined by its use.
>
> If two expressions are used in the same way, then they have the same meaning, or if two persons agree completely about the use of an expression, then they should also agree about its meaning.

Having shown the principle, he introduced three different arguments which support the principle.

1. Meaning has to be communicatable and that communication has to be observable.
2. To learn a language such as that of mathematics is to learn to use it in certain ways.
3. Knowledge of meaning can sometimes have the form of explicit, but, in general, knowledge of meaning is implicit knowledge. Furthermore, implicit knowledge must manifest itself in some way in behavior.

[4] These arguments are quite complicated and still under dispute.

And he added that when we learn how to use a language in mathematics, what we are taught is in general not the truth-conditions of the sentences but what is to be counted as *establishing* the truth of the sentence, that is, *proof*. Thus, the meaning of a sentence is determined by the way it can be proved. In mathematics, the act of proving a sentence is another way of saying the use of it. In this view, the proof is not regarded as an syntactical object but as the sequence of mathematician's proof activity.
Prawitz also introduced different feature of the use of a sentence introduced by Dummett, that is, two aspects of the use of an (assertive) sentence:

1. the conditions under which it can be correctly asserted, and
2. the commitments made by asserting it.

In the case of mathematics, Prawitz explained, aspect (1) is expressed in the rules for inferring the sentence, and aspect (2) in the rules for drawing consequences from the sentence. It is important to note that it should be required a harmony between these two aspects of the use, otherwise the constructed proofs would be inconsistent in mathematical sense.

5 PERSPECTIVE OF CONSTRUCTIVE THEORY OF DESIGN

These ideas of the proof-conditional theory of meaning are surprisingly consistent with the sequence-of-use based theory of design. Mathematics in which objects or proofs are constructed by indefinite repetition of certain procedures which are immediately grasped by the mind is called *constructive mathematics*[5]. This constructively explains the basic idea behind the proof-conditional theory of meaning which puts emphasis on the constructive act of proving. With this awareness in mind, we call the theory of design with the primary emphasis on sequence of use *constructive theory of design*. To give a perspective of the constructive theory of design, above arguments are translated using the terminology of theory of design. (In fact, only subtle changes are needed.)

The principle: meaning of an artifact is determined by use

> The basic idea on which the semantical argument rests is expressed in the principle that the meaning of an artifact is exhaustively determined by its use[6].
>
> If two artifacts are used in the same way, then they have the same meaning, or if two persons agree completely about the use of an artifact, then they should also agree about its meaning.

Three arguments supporting the principle

1. Meaning has to be communicatable and that communication has to be observable.
2. To learn about an artifact is to learn to use it in certain ways.
3. Knowledge of meaning can sometimes have the form of explicit, but, in general, knowledge of meaning is implicit knowledge. Furthermore, implicit knowledge must manifest itself in some way in behavior.

These arguments guarantee that the idea of requirement is indeed testable.

Two aspects of the use of an artifact

1. The conditions under which it can be correctly used, and
2. the commitments made by using it.

It is important to note that it should be required a *harmony* between these two aspects of the use; otherwise, sequence of uses of artifacts would be inconsistent.

[5]For more detail on the constructivism in mathematics, see [30, 31].

[6]In certain cases, people just own products without actually making use of them. However, *owning* is also one way of using the products, since owning them would change their behavior in some ways. If owning them doesn't change their behavior in any observable way, it doesn't have meaning, since meaning has to be communicatable.

5.1 Sequence of Uses

In the case of mathematics, the two aspects of the use (1) and (2) are expressed in the rules for inferring the sentence, such as introduction and elimination rules for logical constants $\vee, \wedge, \rightarrow, \forall, \exists$. If the statement of Martin-Löf "a proof is, not an object, but an act" is accepted, then these rule could be regarded as the rules of (mental) act of proving. If mathematics is actually system of action, the main structure of the system consists of these rules, and proofs are compose of sequence of actions which agree with the rules.

In the case of design, the two aspects of the use are expressed in the rules of using the artifact, and the rule is expressed in people's *tendency* to use it[7], i.e., when given the opportunity, how people are trying to use the artifact. Therefore, if theory of design is about system of action, it is necessary for designers to know the two aspects of the use, since those are the main component of the theory just like the logical constants are the main component of logical system. Then, how can we know these aspects? Because the tendency is regarded as requirement (need) in the constructive theory of design, keys to the answers lie in the answers to the critical question about the requirement.

A1: The conditions under which an artifact can be correctly used can be known by observing how people use it.

A2: The commitments made by using the artifact can be known when people actually use it.

After acquiring these information, designer can have a proof of an artifact, that is, *sequence of uses* of the artifact. This is what designers want in constructive theory of design, since the requirements are satisfied by the sequence of uses.

5.2 Objective of Designing: Conflict and Harmony

But, how we know the artifact is actually correctly used? As mentioned above, the harmony is required between these two aspects of the use to make sequence of uses of artifacts consistent. When there are conflicts between these two aspects, either the condition or the commitment must be inappropriate and, consequently, there must be something wrong with the use. For example, when someone chooses "quit" button from the menu bar of a word processor without saving the document and then the document is lost, he/she will complain or stop using the word processor because this commitment doesn't fit his/her tendency to use the software.

On the other hand, if there is only harmony and no conflict, no design is necessary. Alexander wrote in [3]:

> Under certain conditions, tendencies conflict. In these situations the tendencies cannot take care of themselves, because one is pulling in one direction, and the other is pulling in the opposite direction. Under these kinds of circumstances, the environment does need design: it must be re-arranged in such a way that the tendencies no longer conflict[8].

In scenario writing, drama is said to be *ordered conflict*. So screenwriters try to invent the conflicts and try to create a story where the conflicts dissolve. Contrary, designers try to find the conflict and create a sequence of uses that is free from the conflict. Therefore, one of the objectives in designing in terms of constructive theory of design is that to find conflicts between two aspects of use in a given sequence and create an alternate sequence which does not contain conflicts.

5.3 A Draft of Constructive Theory of Design

Having described the perspective of constructive theory of design, we will briefly show what a constructive theory of design would be like based on Channel Theory[32].

Classification is a mathematical structure for classifying objects.

[7] On the other hand, in mathematics the rule is expressed in mathematicians' tendency to infer sentences.

[8] However, the conflict in the Alexander's sense is about tendencies in the environment not in the sequence of uses.

Definition 5.1. We say a triple $\boldsymbol{A} = \langle \mathrm{tok}(\boldsymbol{A}), \mathrm{typ}(\boldsymbol{A}), \models_{\boldsymbol{A}} \rangle$ is a *classification* if $\mathrm{tok}(\boldsymbol{A})$ and $\mathrm{typ}(\boldsymbol{A})$ are sets[9], $\models_{\boldsymbol{A}}$ is a binary relation between $\mathrm{tok}(\boldsymbol{A})$ and $\mathrm{typ}(\boldsymbol{A})$. We call $\mathrm{tok}(\boldsymbol{A})$ and $\mathrm{typ}(\boldsymbol{A})$ the sets of *tokens* and *types* of $\boldsymbol{A}$ respectively.
Theory is considered to be a set of sentences with some kinds of notions of entailment between theories and sentence.
Definition 5.2. A *theory* is a pair $T = \langle \mathrm{typ}(T), \vdash_T \rangle$ of a set $\mathrm{typ}(T)$ and a binary relation $\vdash_T$ on subsets of $\mathrm{typ}(T)$. A sequent $\langle \Gamma, \Delta \rangle$ of subset of $\mathrm{typ}(T)$ is said to be *constraint* of T if $\Gamma \vdash_T \Delta$, and *T-consistent* if $\Gamma \nvdash_T \Delta$. T is *inconsistent* if there is no T-consistent sequent in $\vdash_T$.
A theory T is *regular* iff T satisfies the following for all types α and all sets $\Gamma, \Gamma', \Delta, \Delta'$ of types:
Weakening: if $\Gamma \vdash_T \Delta$ then $\Gamma \cup \Gamma' \vdash_T \Delta \cup \Delta'$,
Partition: if $\Gamma \nvdash_T \Delta$ then there is a partition $\langle \Gamma', \Delta' \rangle$ with $\langle \Gamma, \Delta \rangle \leq \langle \Gamma', \Delta' \rangle$ such that $\Gamma' \nvdash_T \Delta'$.
Local logic is the structure in order to cope with logics that are both unsound and incomplete.
Definition 5.3. A *local logic* $\mathfrak{L} = \langle \mathrm{tok}(\mathfrak{L}), \mathrm{typ}(\mathfrak{L}), \models_{\mathfrak{L}}, \vdash_{\mathfrak{L}}, N_{\mathfrak{L}} \rangle$ consists of

1. a classification $\mathrm{cla}(\mathfrak{L}) = \langle \mathrm{tok}(\mathfrak{L}), \mathrm{typ}(\mathfrak{L}), \models_{\mathfrak{L}} \rangle$,
2. a regular theory $\mathrm{th}(\mathfrak{L}) = \langle \mathrm{typ}(\mathfrak{L}), \vdash_{\mathfrak{L}} \rangle$,
3. a subset $N_{\mathfrak{L}} \subseteq \mathrm{tok}(\mathfrak{L})$, called the normal tokens of $\mathfrak{L}$, which satisfy all the constraints of $\mathrm{th}(\mathfrak{L})$.

Definition 5.4. A *tree* $T$is an decidable set of finite sequences of natural numbers closed under predesesor; so T is a tree iff

$$\langle\ \rangle \in T, \forall n (n \in T \vee n \notin T), \forall nm (n \in T \wedge m \prec n \rightarrow m \in T).$$

A *spread* is a tree in which each node has at least one successor. So, an element of the spread is a set of finite sequences of natural numbers.
Now we formulate so-called *logic of use*.
Definition 5.5. A *logic of use* $\mathfrak{U} = \langle \mathrm{tok}(\mathfrak{U}), \mathrm{typ}(\mathfrak{U}), \models_{\mathfrak{U}}, \vdash_{\mathfrak{U}}, \boldsymbol{N}_{\mathfrak{U}}, \boldsymbol{D}_{\mathfrak{U}} \rangle$ consists of

1. a classification $cla(\mathfrak{U}) = \langle \mathrm{tok}(\mathfrak{U}), \mathrm{typ}(\mathfrak{U}), \models_{\mathfrak{U}} \rangle$,
2. a regular theory $th(\mathfrak{U}) = \langle \mathrm{typ}(\mathfrak{U}), \vdash_{\mathfrak{U}} \rangle$,
3. a subset $N_{\mathfrak{L}} \subseteq \mathrm{tok}(\mathfrak{L})$ is the normal tokens which satisfy all the constraints of $th(\mathfrak{L})$.
4. $\boldsymbol{D}_{\mathfrak{U}}$ is a function that assigns to a natural number the *situations*, i.e., parts of the world of the given type.

$cla(\mathfrak{U})$ is called the *sequence of use classification*. The tokens of $u, \acute{u}, ...$ of $cla(\mathfrak{U})$ consist of sequences of the natural numbers called *choice sequences*[34] and the types of $s, \acute{s}, ...$ of $cla(\mathfrak{U})$ consist of spreads. Therefore, in $cla(\mathfrak{U})$

$$u \models_{\mathfrak{U}} s \quad \text{iff} \quad u \in s$$

for each token $u \in \mathrm{tok}(\mathfrak{U})$ and each type $s \in \mathrm{typ}(\mathfrak{U})$.
Definition 5.6. Given a sequence of use classification $cla(\mathfrak{U})$, a token $u \in \mathrm{tok}(\mathfrak{U})$ *satisfies* a sequent $\langle \Gamma, \Delta \rangle$ of $\mathrm{typ}(\mathfrak{U})$ provided that if u is of every type in Γ, then it is of some type in Δ. A token not satisfying a sequent is called a *counterexample* to the sequent.
For a set $\mathrm{typ}(\mathfrak{U})$ of spreads, a sequent $\langle \Gamma, \Delta \rangle$ of $\mathrm{typ}(\mathfrak{U})$ will be called a *requirement* on $\mathrm{typ}(\mathfrak{U})$, in the sense that $\langle \Gamma, \Delta \rangle$ specifies a sequence of use which satisfies the sequent.
There are many other notions that need to be defined such as the relationship between the choice sequences and the situations as well as the situation itself, however, to give the detailed formulation as a whole is beyond the scope of a brief paper.

Two aspects of the use

In this way, a sequence of use is expressed by a choice sequence together with a function $\boldsymbol{D}_{\mathfrak{U}}$ that assigns a situation to a natural number in the choice sequence. Here, people's tendency of use is expressed by a set of sequences of use, that is, spread. Therefore, a sequence of use u is fitted into the tendency of use

[9] The "sets" should be understood as *species* in the sence of intuitionistic mathematics (see [33, 34]).

s if and only if $u \in s$. Consequently, the two aspects of the use, namely, the conditions under which an artifact can be correctly used and the commitments made by using it can be depicted by the requirement, that is, a sequent $\langle \Gamma, \Delta \rangle$ of the set of spreads.

Conflict and harmony

To find conflicts between the two aspects of use in a given sequence of uses, we need to know theory on the spreads in the first place by observing how people use it in a given situation. After the theory is obtained, we can see the regularities of the theory, therefore, can know if there are any conflicts in the sequence of uses. If there are conflicts in the sequence, we could create an alternate sequence which does not contain conflicts by reference to the theory and the requirements based on it.

6 CONCLUDING REMARKS

The fundamental characteristics of the concept of meaning in the traditional theory of design, i.e., the existence of model has been discussed and the similarities between the traditional theory of design and the truth-conditional theory of meaning has been pointed out. The argument that the sequence-of-use based theory of meaning could resolve the difficulties in the interpretation of the model by changing the notion of the requirement has been presented. Based on the ideas of the proof-conditional theory of meaning, we showed the perspective of the formulation of the sequence-of-use based theory and discussed about how it could deal with the two aspects of the use as well as the conflicts and the harmonies between them. Future works include that detailed formulation and case studies of the theory.

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Contact: Ichiro Nagasaka
Kobe University
Faculty of Letters
1-1 Rokkodai, Nada
Kobe, 657-8501, Japan
Tel & Fax: Int +81-78-803-5579
Email: nagasaka@kobe-u.ac.jp