

デザインの認知過程における実体的側面と概念的側面 Substantial Aspect and Conceptual Aspect in Design Cognition

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1. Introduction

The objective of this study is to construct a model of a cognitive process in designing. The model is expected to contain formal modules so as to be applied to develop a computational model of thought processes in designing. The computational model could be employed to understand a cognitive process of designing as well as to implement an intelligent system which helps designing. This paper reviews FBS [1] and situated FBS [2] frameworks as the foundation and constructs such a model by introducing a two layered model of experience [3].

2. FBS (Function-Behavior-Structure) Framework

Gero [1] proposes to represent an artifact from three different kinds of aspects, i.e., function, behavior, and structure. He models a process of designing as a sequential cycle of transformations among the representations from the aspect of function, behavior, or structure. This framework for describing designing is called Function – Behavior - Structure framework, or FBS framework (Fig.1).

The notion of *function* refers to the teleological characteristics of an artifact. A representation from the aspect of function shows what an artifact is for. Function of an artifact emerges from the interaction among the artifact, its user, and the environment where the artifact is utilized.

The notion of *behavior* refers to the characteristics of an artifact or the mechanisms of an artifact. The behavior is uniquely derived or expected to be derived from the structure of the artifact and articulates the function of the artifact. A representation from the aspect of behavior shows what the artifact does in a certain system, such as a thermal system, a kinetic system, a legal system, an economic system, etc. The physical properties of an artifact are classified into behavior.

The notion of *structure* refers to the substantial characteristics of an artifact that can be determined directly in

designing. A representation from the aspect of structure describes what the artifact is in terms of its constituent elements and their relationships. A design drawing, or design description, of an artifact is an external representation of its structure. The structure of the artifact determines its behavior.

FBS framework models designing as a transformation from function to structure. Since designing is put into practice in the case that no direct transformation from function into structure exists, the transformation is articulated as a combined process of formulation, synthesis, analysis, evaluation, reformulation, and production of design description (Fig.1).

Formulation, or *specification*, in designing is a process of transforming required function (*F*) to expected behaviors (*Be*). Where, an *expected behavior* refers to the behavior that the designer intends to produce by creating the artifact.

Synthesis is a process of materializing the expected behaviors (*Be*) by determining the structure (*S*) in anticipation of producing the behaviors (*Bs*). Where, an *anticipated behavior* (*Bs*) refers to the behavior that would be derived from the artifact if it were actually made. Beliefs about causal relationships between the structure of artifacts and their behaviors are employed for the anticipation.

Analysis is a process of anticipating the behaviors (*Bs*) of the artifact on the basis of its structure (*S*). *Evaluation* is a process of comparing the produced behaviors (*Bs*) and the expected behaviors (*Be*).

Reformulation is a process of changing the structure (*S*) of the artifact (Type 1 in Fig.1) or changing the range of expected behaviors (*Be*) (Type 2 in Fig.1) and/or changing, through them, the function (*F*) being designed for through the changes in the structure and the behaviors (Type 3 in Fig.1). Reformulation occurs when the produced behaviors (*Bs*) subsume the expected behaviors (*Be*) or when the comparison between the produced behaviors (*Bs*) and the expected

behaviors (*Be*) is unsatisfactory.

Documentation is a process of externalizing the internal representation of the structure (*S*) as design description (*D*).

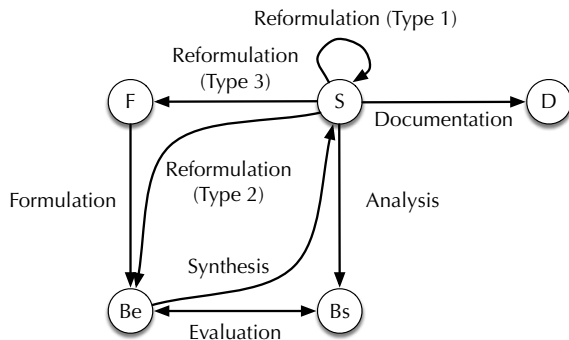


Fig. 1 Model of Design Process with FBS Framework

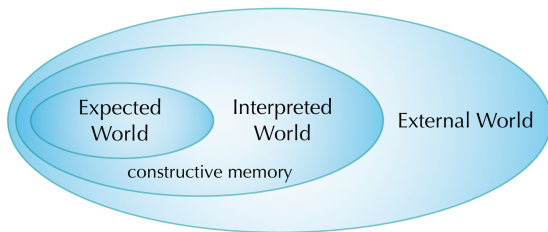


Fig. 2 Three Worlds in Situated FBS Framework

3. Situated FBS Framework

Gero and Kannengiesser [2] sophisticate the FBS framework so as to deal with situatedness in designing on the basis of the assumption by Gero and Fujii [4]. It is assumed that actions in designing are situated in the sense that a course of actions is determined by an interaction between external factors, i.e., the environment where it is performed, and internal factors of the designer, i.e., some goals, beliefs, etc. The framework is called as “the situated FBS framework”.

In the situated FBS framework, the situatedness in designing is modelled as the interaction among the external world, the interpreted world, and the expected world [2]. Fig. 2 depicts the relations among the three worlds. The constituents of the worlds are representations of states of affairs and courses of events. The *external world* is the world composed of representations outside the actor. The *interpreted world* is an internal world composed of the interpreted representation of a part of the external world that the actor interacts with. The *expected world* is the other internal world that is projected as the consequence of the actor's imaginary actions. These three worlds interact recursively with each other through three classes of processes, namely, interpretation, focusing, and action. *Interpretation* is a process of transforming the representation of sensed variables in the

external world into the representation of the things that composes the interpreted world. *Focusing* is a process of focusing on some aspects of the interpreted world and of depicting goals and a course of actions towards the goals in the expected world. *Action* is a process of bringing about a change in the external world according to the goals.

4. A Two-Layered Model of Experience

We are associating another aspect - experience describing the things with which a subject interacts and how the subject interacts with things - with FBS framework. Since the original FBS framework models a design process mainly focusing on a design product, it doesn't explicitly human experience concerning designing. On the other hands, the three worlds in the situated FBS framework implies some processes related to designer's experience.

A change in the external world is brought about by a change in the referents - a state of affairs and a course of events in a substantial system - of some representations composing the external world. We assume that it is our experience that the three worlds represent.

The most comprehensive and fundamental notion of *experience* refers to the interaction between an actor and its external world wherein the actor's action works on the world, changes it, and influences the internal world as well [3]. The interaction, in general, involves the process of doing, seeing, feeling, understanding, or changing the things in the world where the actor and the environment surrounding the actor interact with each other. The experience involves experience of designing, that of implementation, that of utilization, and that of the other things in the lifecycle of a design product (not exhaustive).

Experience, in general, has two aspects, i.e., physical or physiological aspect and psychological aspect. Fig. 3 depicts a hypothetical two-layered model of experience [3].

The *substantial layer* corresponds to the physical or physiological aspect. The interaction between an actor and its environment goes on among the physical and physiological substances, which constitute the actor's body, and the physical substances constituting the environment (substantial aspect in Fig. 3). The interaction is classified into two types. *Conscious interaction* is the interaction recognized with mental reality as conscious experience (conceptual aspect in Fig. 3). *Unconscious interaction* is the interaction going on without mental reality [3]. An actor is a constituent of a system where the substantial entities interact with one another. What an actor directly senses or alters in the system is dependent on the actor's physical and physiological organization and their

relationship with the other entities. The notion of *system* refers to the thing that consists of the composition of matters, the organization of forms, the order of principles, and the relations among them. These constituents of the system let us observe an artifact as its physical structure, its features - behavior and function, and its mechanism coupling the structure and the features.

The *conceptual layer* corresponds to the psychological aspect. The three worlds are located in the conceptual layer. What an actor perceives or conceives in the system is dependent on not only its physical and physiological organization but also its psychological attitude, i.e., intentionality, toward them. We regard this layer as a situation. Therefore, the notion of *situation*, here, refers to a conscious state that is composed of percepts, memory representation, and imaginary representation.

A situation, in general, is a reflection in each of us of the interactions between us and the other things. It figures out what is and has been going on in the substantial system through action, sensation, perception, and conception. We pull particular information from the system with respect to the concepts that are currently active. We passively receive some information pushed by the system as well. The concepts are incrementally formed through our interaction with situations.

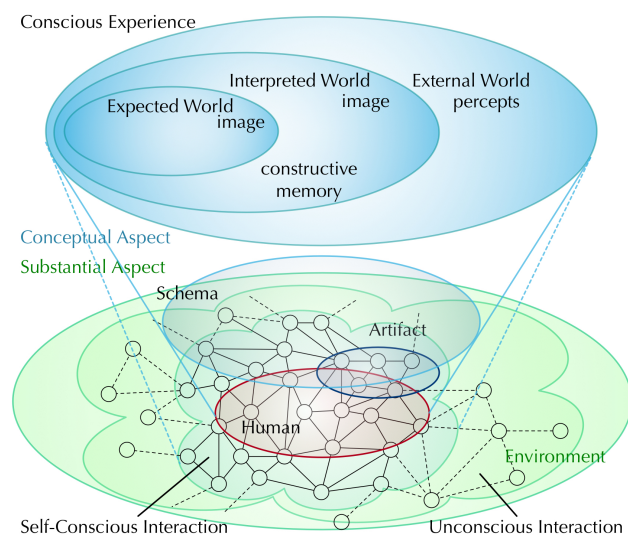


Fig. 3 Substantial Layer and Conceptual Layer of Experience

5. FNS – A Constructive Loop

Designing is an activity making a tangible or intangible thing which wouldn't exist without this activity. The activity involves provision of service of any kind, implementation of a system enabling the service, determination of the structure of a thing to embody the system, construction of the thing, and utilization of the service enabled by the thing. An artifact is an

aggregation of the organization of its constituent artifacts, i.e. the service, the system, the structure, the thing, the experience of service utilization, etc. Each constituent artifact is also an aggregation of the organization of other constituent artifacts.

When we are making an artifact, we are producing the structure of the artifact, the features brought about by the artifact, and the mechanism coupling them, simultaneously. The physical structure is characterized as an assemble of substances. The features of the system emerge out of the interaction of the structure with its environment. The impact of the interaction on the environment as well as on the system is a constituent of the features. Some of the features are expected to appear as a consequence of producing the system. Such expected features are mainly described in terms of the function or behavior. The mechanism colligates the structure and the features.

Constructive loop (Fig. 4) is a unit of constructive activity to fulfill a desire to create a situation where such and such service is provided. The activity is purposive in the sense that an artifact, or at least a part of them, is made consciously on purpose. Such an artifact is implemented intentionally with the expectation to satisfy the desire. It is motivated by consciousness of one's desire to create such and such a situation. An exploration into the nature of things expected to create the situation begins. Awareness of dissatisfaction with something in the interaction with an existing situation becomes the trigger for the desire. The constructive loop assumes the agency of human. We have agency and intentionality and are distinguished from the other entities in the world. We can consciously interact with the world. The interaction produces a situation. We can have expectations about the result and consequence of actions. We can react to unexpected situations [4]. We can perform consequential goal-directed actions such as planning and designing.

A constructive loop starts from any subprocess. The loop is repeated until we succeeded to make the artifact that creates the desired situation or give up the project.

In *scripting* (C3 in Fig. 4), an actor of constructive activity, imagines, on the basis of the memory constructed through experience, how a situation could change if a certain artifact is made. The actor invents some hypotheses that shall fulfil the desire and select the hypothesis that seems promising to the actor. An artifact, or its part, which is consistent with the hypothesis, is designed. The actor anticipates 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 artifact were made.

In *generation* (C1 in Fig. 4), the action of implementing a

plan, which is represented in the expected world, is performed and the organization of the substantial system is intentionally changed as the result. This change causally brings about another change in the system as the consequence. An idea in the expected world is externalized as an artifact or its external representation which is also an artifact.

In *interaction* ($C\sqrt{2}$ in Fig. 4), the actor faces the externalized idea and the result and consequence of the externalization - generation. The externalized thing works as a medium to facilitate the discovery of issues which is not seen in advance.

In *observation*, or *analysis* in FNS, (C2 in Fig. 4), through the experience of the ensemble and the changes in the world, the actor will become aware of new relations among the actor and the world including the artifact. Some of the relations would not be noticed without the experience. Inspired by the new relations, the actor would have desire to create different situation. When an artifact is made, it is analyzed to evaluate if it has the potentiality to provide a situation for the service expected. Whether such a situation is actually created or not is verified through the provision of an artifact and its utilization.

In *scripting* (C3, again), when the fluctuations in the changes are so great that the situation can hardly maintain a consistent balance, a new effective situation, which is expected to resolve the inconsistency, might be desired and a new artifact would be made to create such a situation. The actor's revised understanding of the relations among the actor and the world would be embodied. If it is found that such a situation is not created yet and the desire has not been fulfilled, then constructive activity is continued toward the creation of the situation or stopped. The actor verifies how far the anticipated consequences are consistent with the experiential observations as estimating the proportion of truth of the hypothesis and judges whether the artifact and the hypothesis are sensibly correct, or require some inessential modification to fulfil the desire, or must be rejected. In the former case, if there is inconsistency between the expectation and the anticipation, the artifact is modified to resolve the inconsistency. At the same time, the expectation could be updated since something, which could never be known before the artifact is used but plays an important role in constructive activity, emerges in generation as well as evaluation. The loop involving the generation and evaluation will be continued until the expectation and the observation converge or the resource for the activity is exhausted. Even though the desire is fulfilled, if a new situation brings about another desire, then designing is continued to fulfill the new desire.

Constructive activity has duality in the sense that it

produces an individual thing as well as a general system. In parallel with making an instance system, we are also synthesizing the form, from which things in the same class are instantiated, and formulating the principles, which show certain directions for constructive activity. The system is individual in the sense that it is constructed in order to fulfill particular expectations for the system in a certain situation. The system is general in the sense that applying the system to similar situations may produce similar individuals. The individuality and the generality are mutually necessary even if it varies in accordance with interests in constructive activity on which the emphasis falls. A general system is constructed through the abstraction of interested features from an individual system. The general system is transmitted from the original individual system to other individual systems by producing them. An individual system is constructed by embodying the form made up with interested features of a general system in the formation of matters.

6. Conclusion

A model expressing substantial aspect and conceptual aspect in design cognition is explained.

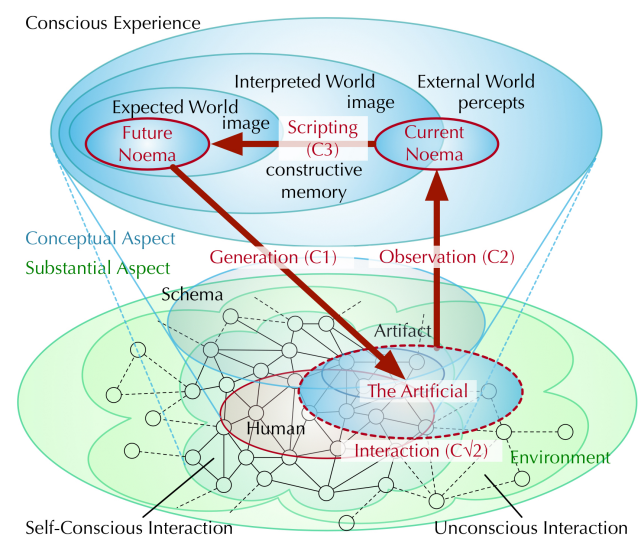


Fig. 4 A Constructive Loop on a Two-Layered Model

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