# Proposing Designology

## Inquiry into Activities of Design and Inquiry into Design

Haruyuki Fujii*, Hideyuki Nakashima**, Masaki Suwa***

** Tokyo Institute of Technology, fujii.h.aa@m.titech.ac.jp*
*** Future University Hakodate, h.nakashima@fun.ac.jp*
*** Keio University, suwa@sfc.keio.ac.jp*

Abstract: The foundations upon which we inquire into methodology of the science of the artificial are being designed. We name the activity of designing the foundations *designology*. This paper proposes a model of design activities and that of study of design activities, with which we establish the foundations of a state-of-the-art methodology of the science of the artificial. A design product is a new system modeled as a set of features and relations among them. The new system is integrated with existing systems and becomes a part of complex systems. We model design process as a constructive process by sophisticating the model of problem solving processes. Design and inquiry into design are concurrent processes. Designology has recursive structure in the sense that it does design practice where a methodology of inquiry into design is designed and that the product and process of the design practice are subjects of inquiry into design in designology. Therefore, the constructive methodology of designing something is also a methodology of designology.

***Key words: Designology, Inquiry into Design, Constructive Methodology, FNS Diagram***

### 1. Introduction

We are designing the foundations upon which we inquire into methodology of the science of the artificial. We propose, in this paper, a model of design practice and research for the purpose of establishing a state-of-the-art methodology of the science of the artificial. We are naming the activity of constructing the foundations *designology*.

The principal subject of the science of the artificial is the methodology of coupling design researches and design practices. The purposes of design researches are 1) to inquire into the fundamental principles to understand and explain the nature of design and 2) to devise methods of applying the principles to cultivation of our design mind and to improvement of the quality of design practice. The purposes of design practice are 1) to devise a method of changing a situation into preferable one and 2) to make use of the method to improve our quality of life. Designology is aiming at a comprehensive method of making design researches and design practices closer with each other.

We are becoming to realize that it's not always appropriate to apply the methodology of natural science to the science of the artificial, even though the methodology of natural science is established well to throw lights on the hidden orders in things and affairs. In natural science, objects or matters to

be studied are analyzed by reducing them to the elements measurable from an external point of view. The objects or matters that cannot be reduced to such externally measurable elements are hardly dealt with for discussions. It is not appropriate to assume that everything related to design is comprehended through the methodology of natutal science by translating the mysterious whole into quantitative language by a method acknowledged socially to be established one. The basic principles of natural science, which are objectivity, generality, and logicality, do not always fit for the science of artificial. The science of the artificial deals with man-made things and cognitive processes enabling the activities of designing the artificial. It could be safe to say that subjectivity, individuality, locality, and intuition (not necessarily logical) also play important roles in design activities.

As far as we know, the constitutive principle of objects or matters is one of the things that have not been represented in terms of measurable matters, but it plays an important role in design activities. To design is to create something new that can scarcely exists without an activity of creating it. The artificial is not derived automatically from preceding things only by the law of causality. The principles of creating something are immanent in the creators as well as in the relation between her/him and the things in the world. As it is hard to answer the question of what is living is by analyzing externally measurable elements k composing life-forms or a biological activities, it is hard to find an appropriate answer to the question of what designing is by analyzing externally measurable elements composing design products or design activities.

Our proposal is inspired by Akin's pioneer work and Gero's vigorous work. Akin [1] developed models of the cognitive mechanisms of the designers based on the empirical data acquired from design experiment and a computational model of design thinking. The motivation underlying his work is to develop the foundations for an information-processing theory to be used to bridge architectural practices, researchs , and educations. The cognitive processes in design are classified into projection of information, acquisition of information, representation of information, confirmation of information, and regulation of flow of control. Gero [2] proposed a formal model of design process as a process of transforming functions to be provided into a design description of a design product that is expected to have the potential to provide the functions. The activities in design are classified into formulation of a design problem, synthesis of a design product, analysis of the solution, evaluation of it, reformulation of the problem, and production of the design product. The commonality between the Akin's work and the Gero's work is that both focusing on design thinking and model its processes as recurring of a cycle in which both design problem and design solution are elaborated through their generation, analysis, and formulation.

## 2. Methodology

Designology is being designed on the basis of our experience and intuition as well as theoretical thoughts. We are introspecting our own mind as individuals who are involved in design as well as inquiry into design. Introspective intuition comes form our experience in design practice of buildings, smart cities, artificial intelligence, learning methods, etc. Theoretical thoughts are derived through

reasoning grounded on our experience of inquiry into design in architecture, intelligent informatics, cognitive science, etc. We would rather venture to approach this issue with the first person point of view than examine it by a natural scientific method. This is a tentative approach to a methodology of the science of the artificial. One of the methods of looking at designer's mind is to introspect our own mind as if we were designers. However, it is hard for novices in certain design fields to feel like experts who are active at the forefront of designing in those fields. Only who designs can approach the depths of design. A constructive method [5, 6, 7] is applied to design of designology. The constructive method is explained later.

## 3. A Model of Design

This section describes models of design product and design process quasi-formally to show how designology sees findings from design research and design practice. Design product is modeled as a subsystem of an existing complex system, which is the environment where the design product is constructed. Design process is modeled as problem solving process to create a new system to change a situation into a preferable situation by letting the system interact with the environment.

One of the major concerns of design is to produce services so as to be capable of bringing about a preferable situation. Services start when the systems for the services are activated and interact with the environment. It is narrated from a diverse range of aspects if a situation is preferable or not. Almost all of the aspects concern with the quality of life. Services are programmed in expectation of improving the quality of life. Installing artifacts incarnates systems, which work as device for the services. Services emerge upon behavior of the systems.

We define design as a class of activities involving the following phases; 1) creating a new system that provides a way to change the current or anticipated situation into a preferable one, 2) incarnating the system by assigning entities to the formation of the system, and 3) activating the system by putting it in a certain environment and letting it interact with the environment. Its constituent matters and the relations among the matters define the formation of a system. Its constituent entities and the relations among the materialized entities define the materialized form of a system. Through interactions between a system and the environment including the users, the functionality of a system emerges. The design product becomes an integral part of life. They change lifestyles more or less. New requirements arise from experience of new lifestyle. A new system is created. This mutual recursion is repeated.

Design products - things designed - are artifacts. The notion of artifact refers to a thing that one consciously makes by using a method that one consciously makes. The boundary between what is being designed and what is not being designed depends on the designer's range of awareness and consciousness and is not always conclusive. Services provided through the interaction among recipients, providers, devices, and environment as well as devices themselves could be artifact.

The domain of the design ranges from tangible things to intangible things. A stone implement, a machine, a building, etc., for example, are tangible things, whereas a program, a plan, theory, methodology, entertainment, etc. are intangible things. Materialized elements incarnate a tangible

system or works as a vehicle for an intangible system. For example, a house connotes a system of spaces providing the occupants with a place to live in peace and to keeping their foods and properties from the external threat, a thermal system keeping a genial indoor climate from the hostile outdoor climate, i.e., the rain, the wind, the heat, the cold, etc., and a structural system of materializing the roofs, the foundations, the walls, the openings, etc. These systems are incarnated in the house by building it with physical entities and activated by settling in it. It is an activity of building environment to build a house. It is also an activity of building environment to live in the house.

### 3.1 Design Product as Complex System

To design is to alter an existing complex system by changing its subsystem. A newly created system is integrated with existing systems. The former and the latters are organized into a sophisticated system. The new system becomes a subsystem of the sophisticated system. The behavior of the subsystem is influenced by the behavior of the sophisticated systems. The former influences the latter, too. The new system are integrated into macro systems in some cases, or micro systems are integrated into the new one in the other cases. The sophisticated system and other sophisticated systems are integrated with each other and organized into a more sophisticated system, recursively. The systems on the upper bounds of the ordinal relation of sophistication relation become the whole systems, i.e., the world.

A system is classified into three categories with respect to the range of availability of control, i.e., core system, proximal system, and distal system. A *core system* is a system incarnated by the artifact characterized made only of the features that can be determined or controlled directly by the designer. A *proximal system* is a system where the core system and the proximal environment interact with each other. The behavior of the proximal system is explicit in the sense that the features characterizing the proximal environment could be controlled indirectly by defining the core system. A *distal system* is a system where the core system, proximal system and the distal environment interact with one another. A distal system emerges upon the interaction. The behavior of the distal system is implicit in the sense that the features characterizing the distal environment could only be harnessed by indirectly controlling the proximal system. Fig.1 depicts the relation among the core system, the proximal system, and the distal system. The systems are characterized by the elements depicted as the node, their properties, the relations among the elements depicted as the links between nodes, their properties, the relations among the relations, their properties, and so on. These characteristics are expressed as a set of the features explained in the next section.

A design product such as a device or vehicle incarnates a core system. A proximal system is produced by the interaction between the device and the user. A distal system emerges as the side effects brought about by the usage of the device. For example, a building incarnates the thermal system that controls the indoor climate as one of core systems. The thermal system is activated by constructing the building in a certain environment and by living in the building. The core system is activated in the proximal system incarnated by the building, the occupants, and the ambient surrounding. Such a

proximal system forms a mesoscopic environment system. The proximal systems are coupled with each other and the distal system, i.e., global environment system, emerges upon the proximal systems.

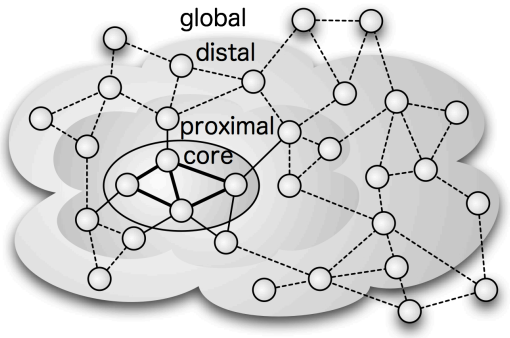


Figure 1. Core, Proximal, and Distal Systems

## 3.2 Design Process

### 3.2.1 Design Process as Process of Problem Solving

Design process is modeled as problem solving process [3]. Problem solving in design is formalized as follows: given a set $P$ of all forms, find an element of the subset $S$ of $P$ having certain properties. Where, a form corresponds to a system building relations between an artifact and its environment. We extend the problem-solving model. The goal of design and the activities towards the goal are, however, vague and not defined well beforehand. Since design is aiming at a future situation, which we haven't experienced or don't know well, it is hard to define the goals completely in advance. We don't know, in advance, the features to be enumerated sufficient enough to define the forms, the requirements, and the constraints since we don't know exactly what design solutions ought to be or how to derive a design solution efficiently without doing design. The problem is not well defined, either, for the similar reason.

As a matter of convenience, we assume that the properties of forms are expressed in terms of a subset of a set of all features each of which corresponds to a certain property of forms. The features are classified into four classes with respect to the accessibility to the features. *Determinable features*, or D-features, are the features that a designer can directly determine. *Controllable features*, or C-features, are the features that a designer can control indirectly by determining the determinable features. *Affectable features*, or A-features, are the features that a designer could indirectly and qualitatively control by associating them with D-features and C-features. *Emergent features*, or E-features, are the features that a designer can harness by controlling the controllable features or affectable features. In this formalization, it is necessary to enumerate all features available for expression of the forms. To enumerate the features implicates to define the range of awareness and consciousness in the design problems formulated in terms of the features. A set of all forms corresponds to a set of all subsets of the enumerated features. Let $P_D$, $P_C$, $P_A$, and $P_E$ be a set of all D-features, that of all C-Features, that of all A-features, and that of all E-features, respectively, then the set of all subsets of the union of $P_D$, $P_C$, $P_A$, and $P_E$ corresponds to the set of all forms expressed by those features. The properties required to design solutions and the properties constraining them are defined as a subset of the enumerated features. It is

evaluated whether a candidate of design solution is actually a design solution or not by testing whether the candidate has all of the features defining the requirements and constraints to the design solution.

In problem solving, generate and test is a general strategy to solve a problem [1]. The process of design problem solving is basically simple as problem solving process. The first move is to make a candidate to start off with. It is enough at this point for the candidate to fulfill some of the requirements and constraints. The first candidate is a foothold from which the second candidate is generated. It is expected that the second candidate should increase the number of the features that fulfill the requirements and constraints. The candidates are generated until a design solution is generated.

The process of design problem solving is somewhat complicating, too. The enumeration of all of the features cannot be done completely in advance as mentioned above. Some features are found or some are eliminated during designing. In these cases, the set of all features would be revised and the goal of design would be re-defined. In addition, generation of a candidate of design solution is accompanied by design thinking. Inquiry into how to design is one of the tasks assigned to designers. The designers explore answers to the inquiry through their own experience of design by the approaches that only who designs know. We are constructing an extended generate and test strategy as a constructive method [5, for example]. The current version of constructive methodology is explained in section 4.

### 3.2.2 Reasoning of Purposive Action in Design

Generation of a candidate involves a purposive action. It is true that it is sometimes done arbitrary though. Fig.2 shows a model of process where a designer intends to do something to change a situation into a preferable one. Let *Sc* be the current situation. If the designer realizes that *Sc* is unpreferable then the designer will desire to change it. If the designer anticipates that a certain event likely occurs and the event brings about unpreferable situation *Sfa* even though *Sc* is not unpreferable then the designer will desire to avoid facing the unpreferable situation, too. If the designer estimates the probability of the event to be high and the desire is strong enough then the designer plans to do something to change *Sc* into another situation where the occurrence of the event does not bring about an unpreferable situation.

In the case that the designer has a schema concerning the causality that a certain action is effective to change the situation into a preferred one, the designer intends to perform the standard action. On the contrary, in the case that the designer does not have the schema that such a standard action is effective, the designer, first, plans a course of actions to change the situation into a preferable one, and then, the designer follows the plan. In the second case, a plan is made as follows. The designer pictures intermediate situation *Sfi* where the event does not bring about an unpreferable situation *Sfa* but a preferable one *Sfe* on the basis of the schema involving the causality associating the event with its consequences. It is assumed that the preferable situation *Sfe* can be brought about not directly by the designer's action but indirectly by the designer's action and the events following the action since it is one of the possible consequences brought about by the event that is not controlled by the designer. It is also assumed that a designer can control the intermediate situation to some degree. Then, the designer makes a plan to directly change *Sc* into *Sfi* and expect the preferable situation *Sfe* to be brought about.

Here, situation *Sfe* is directly brought about or controlled in the sense that the significant features characterizing the situation are D or C-features and can be directly changed or controlled by a designer. A situation is indirectly brought about or controlled in the sense that the significant features characterizing it are A or E-features and could be harnessed only indirectly by changing certain D-features. It is not necessarily straightforward to picture an intermediate situation from which the expected preferable situation is emerged through the presumed event.

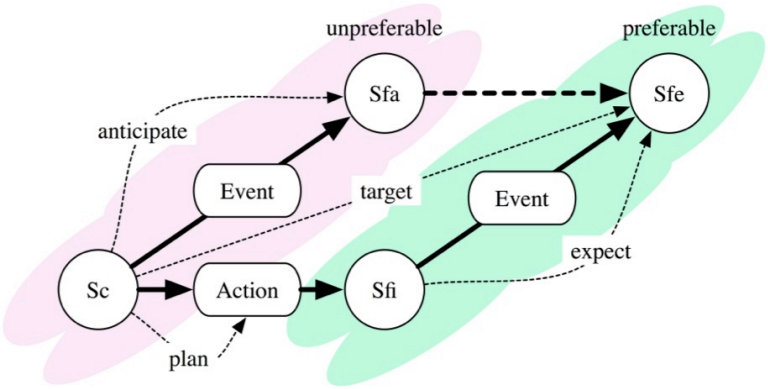


Figure 2. A Model of Intentional Action

## 4. Designology

### 4.1 Framework of Designology

The objective of designology is to create and update the foundations upon which we discuss on the methodology of inquiry into the activities of design where design practice and design research are coupled and investigated as a whole. Fig. 3 depicts the activities concerned in designology. The lower right boxes express the activities of design, which is domain specific such as architectural, artificial intelligence, etc. The upper left box expresses the activities meta-design where design is designed. Design is composed of design practice and design research. The former and the latter are mutually related in the sense that the subject of design research is design practice and its product while the goal and the method of design practice are influenced by the findings in design research. Inquiry into design should not be done independently of design, and design necessarily goes with inquiry into design.

The principal subject of designology is a class of activities where design and inquiry into design are mutually associated. Design practice are classified into artifact design and method design. *Artifact design* is design practice in the narrower sense. The product of artifact design is an artifact in a certain domain that is expected to have the potential to provide designated functionality. The artifact is the thing embodying a method of changing a situation into preferable one. *Method design* is design practice where a design method of designing a particular class of artifacts and a design method of method design are devised. Inquiry into design, i.e., design research, is classified into inquiry into design process and inquiry into design product. *Inquiry into design process* aims at the fundamental principles

to understand, explain, and preach the nature of design process. *Inquiry into design product* aims at the fundamental principles to understand, explain, and preach the nature of the artifact and those underlying the phenomena brought about by interaction between the artifact and the environment.

The designology involves design practice and design research as design involves them. The activities of design practice in designology are classified into inquiry design and method design. *Inquiry design* is design practice in thorough methodology of inquiry into design is produced. The methodology is a framework upon which a method of inquiry into domain specific design is built. *Method design* is design practice where a design method of inquiry design and that of method design are devised. The activities of inquiry design and its product, i.e., inquiry method are the subjects of inquiry in designology.

Designology and design have similar structures as shown above. In addition, designology has a recursive structure. To design a method of design research is design practice that is inquired into in design research. Therefore inquiry into design connotes design. To think what design is and how design ought to be inquired into are also connoted in both inquiry into design and design.

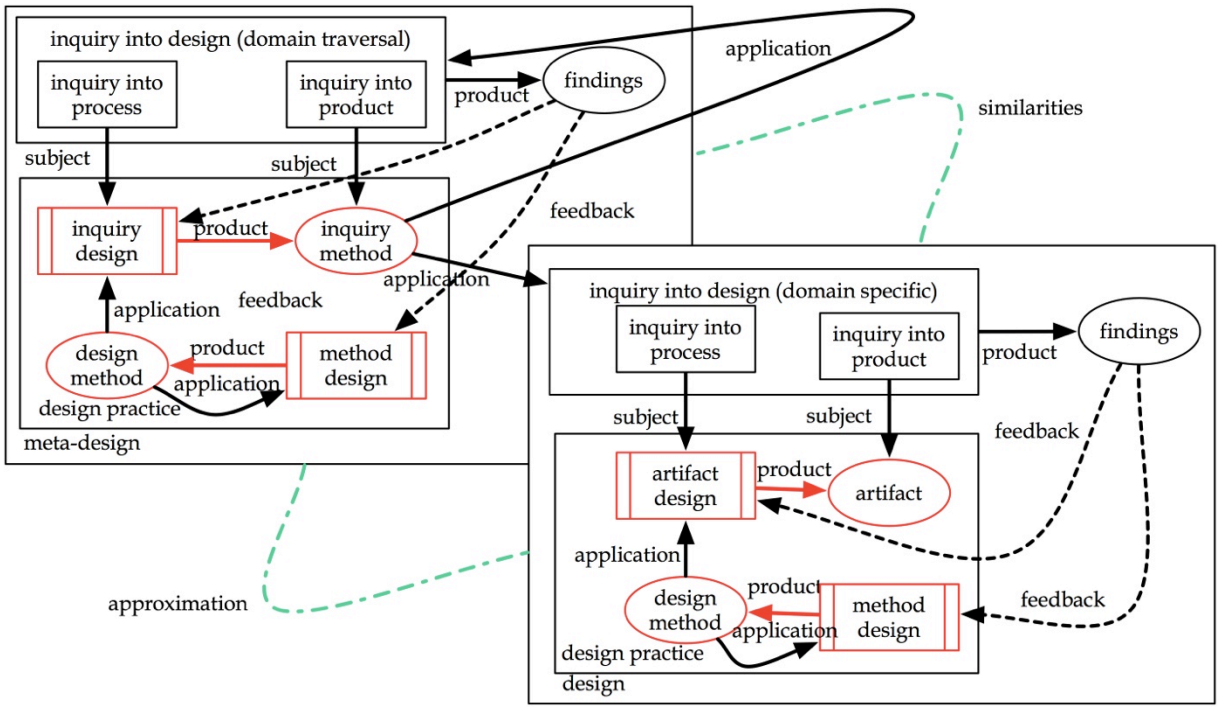


Figure 3. Framework of Designology

## 4.2 Constructive Method of Designology

The activities of design studied in designology are constructive. Both process of design practice and that of design research are constructive. Process of designology is also constructive. The goals of the activities and the activities to reach the goals are being constructed successively as they progress. A constructive method of creating something is recurring of cycle composed of generation, interaction, analysis, and scripting [5, 6, 7]. Each process has the recursive structure composed of smaller cycles of generation, interaction, analysis, and scripting. Logical thinking and intuition are used in the

constructive method. Fig. 4 depicts a constructive loop which we call *FNS diagram*. The following four sections explain the core conceptions in FNS diagram, i.e., future noema and current noema, generation, interaction, analysis, and scripting. FNS diagram is originally designed to model design process. FNS diagram can be applicable to inquiry into design since inquiry into design is constructive process.

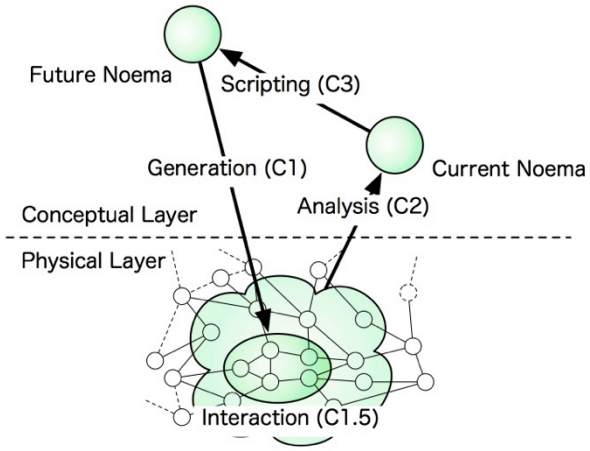


Figure 4. FNS Diagram

### 4.2.1 Future Noema and Current Noema

We introduce the notion of *future noema* and that of *current noema*, inspired by phenomenology, to express a model of activities of design from an internal point of view of the actor involved in the activity. Noema is a representation acquired through the intentional noesis activity of the agent. Noesis refers to the agency of intentionality with which one affects the external world and the actor's understanding of the world. Noesis gives the substances into the representation. Husserl employed noesis and noema for the phenomenological analysis and description of intentionality. The future noema is a representation of a situation anticipated. The representation is autogeneous in the following sense. *Autogenous representation* is a reflection of the situation that we are anticipating. It is detached from the current appearances of the external world and not governed by it, even though it could be associated with it. The scheme with which we see the world also influences autogeneous representation. An autogeneous representation expresses the idea about a hypothetical situation that is derived based on the current schema or that are imagined by making a wild guess. Some of the hypothetical situation could be turned into in the future. Some could have been turned into in the past. The current noema is representation of a situation experienced currently by a designer. The representation is exogenous. *Exogenous representation* is a reflection of the situation we actually faces. It dynamically changes from moment to moment as our understanding on the relations between the external world and us. Though, it is directly governed by the current appearances of the external world, it differs from the photorealistic live coverage of the world. The schema with which we see the world influences exogenous representation. The features and the relations among them that are relevant to the schema employed are extracted to make representation. Some are added, deleted, or biased.

### 4.2.2 Generation (C1)

*Generation* is composed of two sub-processes, i.e., fabricating and activation. Action with physical movement is required since the essence of generation is to change the external world. In *fabricating*, the conception elaborated internally is incarnated as a form or a vehicle externalizing the core system included in it and it is inquired of the external world whether the conception is grounded on it. The internal conception is materialized as a certain structure of entities in the external world and exposed to the environment. In *activation*, the externalized conception is operated to interact with the environment. Activation contains a process of carrying a plan devised after logical deliberation to fulfill the purpose as well as a process of trying to employ or make something intuitively for the present in the hope of promoting the purpose. The external world is altered. The conception is externalized as memorandum, sketches, drawings, models, finished products, drafts, papers, etc. The finished products are clothes, houses, instruments, machines, devices, systems, methods, services, lifestyles, hypotheses, design methodology, art, technology, etc., in design, and hypotheses, knowledge, wisdom, experimental equipment, research methodology, scientific principles, theses, treatises, etc., in inquiry into design.

### 4.2.3 Interaction (C1.5)

The externalized form or vehicle of the conception is activated in the environment and interacts with the environment. When the conception is externalized and exposed to the environment, the externalized entity interacts with other entities already existing in the environment. The interaction results in the change of the states of affairs in the world and brings about a certain phenomenon. It should be emphasized that the interaction occurs in the lower level of the current noema and the future noema in the sense that it affects on the entities as well as the representations. Proximal systems are produced by cooperation of a newly produced core system and its neighbor existing systems. The newly produced systems transform the whole system. Distal systems emerge upon the interaction among the core system, the proximal systems, and the whole system. We call this process as *interaction*. The frequency and impact of the interaction as well as the time span and the effective range of the phenomenon depend on the relations among the entities. Unexpected things could happen through interaction since everything is not within the anticipation. One of the significances in interaction is to experience unexpected things and to find the features and relations among them to be noticed.

### 4.2.4 Analysis (C2)

*Analysis* is composed of three sub-processes, i.e., observation, evaluation, and narration. In *observation*, the progress, the result, and the consequence of the preceding process of generation and interaction are perceived. Behaviors of a core system and the proximal systems are observed. Behaviors of the distal systems are observed occasionally. Those progress, result, and consequence make the current situation. Emergent and unexpected things are found serendipitously. In this case, the designer often changes the ways of observing the current situation. In *evaluation*, the current situation is compared with the anticipated picture of the conception envisioned prior to the preceding generation is realized in the process of evaluation. It is evaluated whether a process of designing is on the right track,

whether the anticipated situation is approaching, and so on. In *narration*, the thing that is understood about the current situation and the relations between it and the anticipated situation is conceptualized and explained. When there are significant differences between the current situation and the anticipated one, it is reasoned and explained what makes the differences. Sometimes, new features are introduced for the explanation, especially when the designer changes the ways of observation. Such features would be used to sophisticate the definition of the design problem. A particular schema is employed to perceive the things in analysis. The observation, evaluation, and narration are basically made upon the schema. It depends on the schema and the flexibility of the analysis if the emergence is captured.

### 4.2.5 Scripting (C3)

*Scripting* is composed of three sub-processes, i.e., anticipation, envision and scripting. In *anticipation*, the designer anticipates what if a certain thing happens, or what if the designer does a certain thing. In *envision*, the designer envisages the situation that the designer intends to head for. In *scripting*, the designer writes a scenario, which is hopefully promising, including a course of action reaching the intended situation. The current milestone, the aspect concerning how to evaluate whether the milestone is reached, and the strategy to generate an artifact that gets good consequence in the coming evaluation are focused. Succeeding generation and analysis would be performed in accordance with the scenario.

A particular schema, through which the things are perceived, is employed in scripting. The schema reflects the current concern. It may be replaced another schema fitting to observation of the situation unexpectedly encountered. Some features that seem to be notable to represent the current schema are focused while some features that seem to be irrelevant to them are temporally pruned to reduce the space explored. The trajectory towards the future situation is adjusted reflecting retrospection of the locus from the past. It occasionally happens that the trajectory changes drastically when new attractive and promising features are found or the current schema is replaced by another schema. A course of action for the succeeding generation and analysis is directed with respect to the schema.

## 4.3 Coupling Design and Inquiry into Design

It is suggested that design and inquiry into design share a common place of practice. Focusing on inquiry into design, it is important for scientific hypothesis and principle concerning design to be applied to design practice. Theories on design should go hand in hand with design practice. A scientific hypothesis that survives practical testing becomes a scientific theory. Focusing on design, scientific hypothesis and principle concerning design enable the designer to use them to think what to design and how to design. Design thinking is affected by the promising hypothesis and principles. Since both design and inquiry into design are constructive processes, they share a common place as shown in fig. 5. FNS loop of design and that of inquiry into design interact with each other in the physical layer. Design applies the principles and theories created through inquiry into design. The principles and theories are elaborated on the basis of how they are used in design and inquiry into design.

It is also suggested that one who makes inquiry into design is also one who designs. It encourages us to makes inquiry into design from the first person point of view as a designer as well as a researcher.

The things not reduced to externally measurable matters are not are hardly taken up for discussion even if we intuitively know that the things are important. If a researcher and a designer are the same, it is possible to observe the things from the first person point of view as a researcher as well a designer. It is also possible to observe objectively the things. Since inquiry into design connotes design practice a researcher is also a designer in the sense that both are the performers of the constructive method.

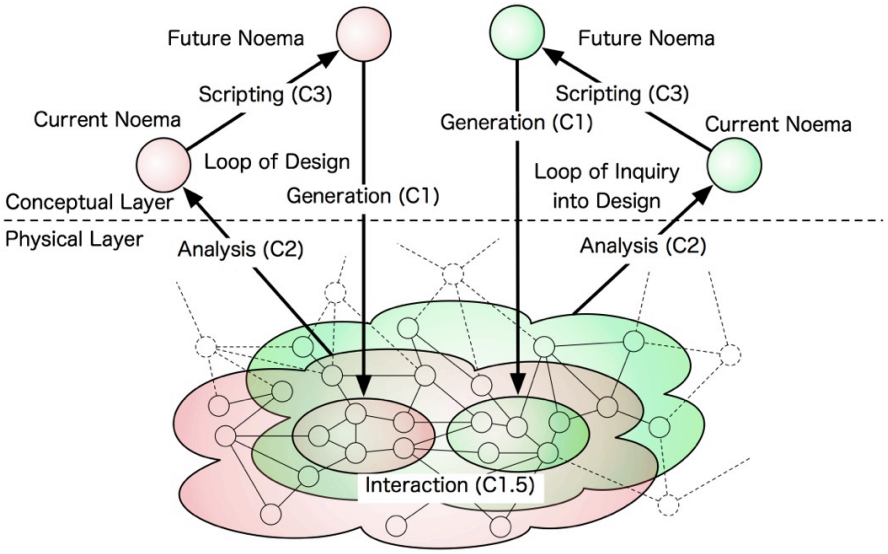


Figure 5. Place of Practice Shared by Design and Inquiry into Design

## 4. Conclusion

The foundations of designology are proposed. A constructive methodology of design and inquiry into design is proposed. The implication of this methodology is that designing and inquiring into design should preferably be conducted parallel to feed obtained insight from one to the other.

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