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A UNIFIED APPROACH FOR SYSTEMATIC AND PARTICIPATORY DESIGN

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ABSTRACT
Engineering design has taken an important role in creating the industrial society. The systematic design approach which consists of the design methods and methodologies based on systematic models and processes is commonly applied in various design fields and industries.
Meanwhile, participatory design is another common design approach to explore the requirements of a product and its users' activities by participating in a user field based on the social science background. These two approaches have different disciplines and used to be separately studied, though they have a complementary relationship. To harmonize these two design approaches, it is necessary to understand their concepts, features and challenges, and to clarify the requisites to unify them.
In this paper, the authors introduce the systematic design methodologies and the participatory design approach based on the theoretical survey and explain their features and challenges. Then the authors suggest a possible way to unify both design approaches, propose a concept of integrated design approach named "User-driven Product/Activity Design (UPAD)" approach and discuss its effectiveness and uniqueness.

Keywords: design theory, design process, participatory design, systematic design, user-driven product/activity design

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1 INTRODUCTION

Engineering design has taken an important role in creating the industrial society. Especially, the design methods and methodologies based on systematic models and processes such as the design methodology by Pahl and Beitz (1988) are commonly applied in industries. The authors call the approaches of such design methodologies as "systematic design approach." The systematic design approach is characterized by its objectivity and strictness, and it was essential for the separation of product design and production to realize mass production. The concept of the systematic design approach has become widespread in various design fields, such as software design (ISO/IEC, 2008) and service design (Shimomura and Tomiyama, 2002).

Meanwhile, participatory design (Greenbaum and Kyng, 1991) is another common design approach to explore the requirements of a product and its users' activities by participating in a user field based on the background of social science. This design approach is effective to extract and analyze these requirements from the viewpoint of users.

These two approaches have different disciplines and used to be separately studied. Recently, several researchers attempt to utilize both approaches to harmonize a product and its users' activities. However, the methods of the participatory design approach such as a workshop tend to be used just as a means to determine design concepts and the methodological aspects of the participatory design approach have not been sufficiently considered from the side of the systematic design approach. On the other hand, detailed design and development of products are usually out of the scope of participatory design researchers. Some researchers pointed out that the ethnographic approach in participatory design contributes product design less than its potential (Dourish, 2006). To harmonize these two design approaches, it is necessary to understand their concepts, features and challenges, and to clarify the requisites to unify them.

In this paper, the authors attempt to build a bridge between two design approaches for the product and activity design in a work environment based on the theoretical survey. First, the authors introduce existing systematic design methodologies and figure out the challenges they confront. Next, the authors explain the participatory design approach in a broad sense, its effectiveness from the aspect of the systematic design approach and remaining problems. Then the authors suggest requisites to unify the systematic and participatory design approaches, and propose a concept of integrated design approach named "User-driven Product/Activity Design (UPAD)" approach. The concrete methodology of this design approach is being developed through actual system development in several service fields. The authors introduce current research activities and discuss its effectiveness and uniqueness.

2 SYSTEMATIC DESIGN APPROACH AND ITS CHALLENGES

2.1 Concept and existing methodologies

The systematic design approach is a design approach to determine specifications of design objects by means of well-structured models based on a specific engineering domain. This approach is intended to clarify specifications in a structural manner and often applied in engineering design because of its validity and reliability.

The systematic design approach is applied in various design research fields. In this study, the authors investigated major methodologies and models of the systematic design approach in the fields of product design, software and system design, and service design.

2.1.1 Methodologies of product design

The product design research has a long tradition especially in Germany and most of the proposed methodologies are categorized in the systematic design approach. One of the most famous design methodologies is the product design methodology by Pahl and Beitz (1998). This design methodology provides concrete and systematic design process and methods for product design. As another example, Suh (1998) proposed Axiomatic Design which consists of two main design axioms and algorithmic concept of design. In this design concept, design is considered as a mapping between elements in different domains such as a mapping from functional requirements to design parameters.

2.1.2 Methodologies of software and system design

Computers and information systems have become essential elements for any kind of products. For the design and development of them, a software and system engineering process has been standardized (ISO/IEC, 2008) and various methodologies to design software and systems have been developed (for example, Kotonya and Sommerville (1998)). The most famous systematic model for software and system design is Unified Modeling Language (UML) (OMG, 2010). It is a set of models to describe certain aspects of software or information systems.

Meanwhile, the influence of human factors is an important issue in the software and system engineering field. For example, many researchers have been studying Human-Computer Interaction (HCI) actively since computers have good interactivity and the user experience through HCI influences his or her satisfaction strongly. To fit a designed system to users, the cognitive process and the physical features of humans have been surveyed and modeled in a systematic manner. For example, Card et al. (1986) developed a model of human cognitive processes, which is useful when a system developer determines the reaction speed of information systems.

As another research issue concerning human factors, business process analysis methods for the implementation of enterprise systems can be taken up. One of the most famous methods is Business Process Modeling Notation (BPMN) (Stephan, 2004). BPMN was developed to describe a business workflow organized by humans and information systems. The described workflow is used for business process reengineering and the design of new information systems.

2.1.3 Methodologies of service design

Recently, products are easily commoditized and it has become difficult to sustain their value. Therefore, many researchers focus not only a product itself, but also service processes related to the product as design objects. Several systematic design methodologies have been proposed to design services. For example, Shimomura and Tomiyama (2002) have proposed a service design methodology based on the function-oriented design method. As another example, several researchers such as Morelli (2002) and Hara et al. (2009) proposed modeling methods of service processes composed of human activities and product behaviors.

2.2 Summary and Challenges

2.2.1 Basic concept of the systematic design approach

The basic concept of the aforementioned methodologies can be summarized in Figure 1.

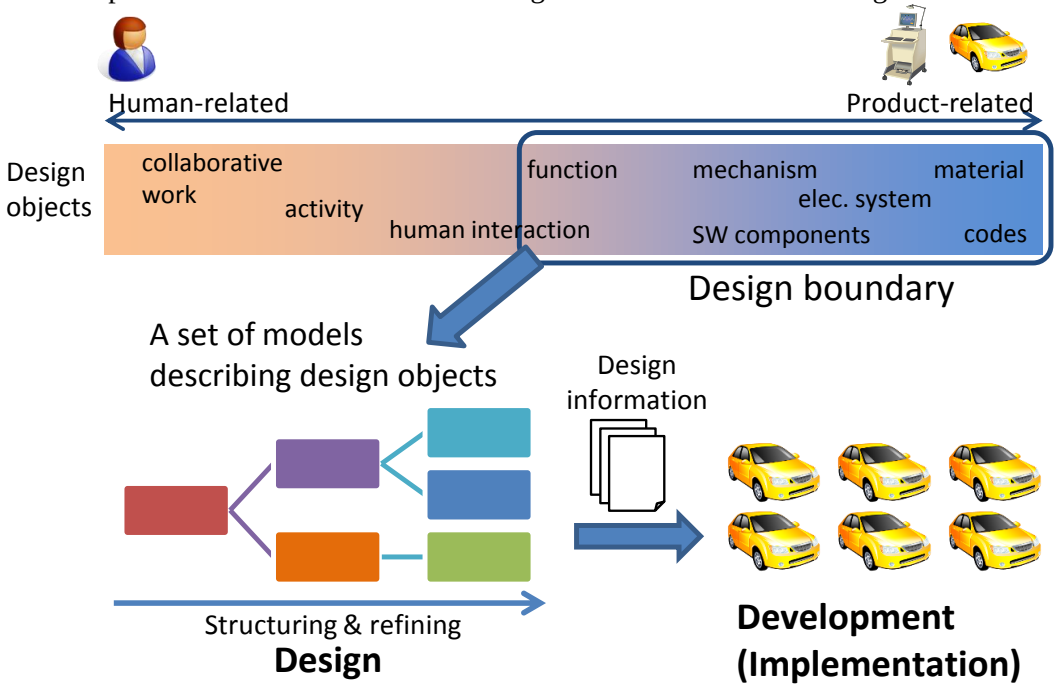

Figure 1. Schematic description of the systematic design approach

The systematic design approach premises the "design boundary" to determine design objects. To describe such design objects, a set of models are prepared. Each model expresses a certain aspect of a design object. The model used in design should be well-structured to explain whole phenomena within each model's domain. The common design models are: functional model (for example, Umeda et al., 1996), geometric model, physical model (such as kinematic and electric) and process model. Each model is related to one another and is refined through design processes. By using these models, the detailed design information is extracted.
After the design, design objects are developed or implemented according to the design information. The design information is expected to be detailed sufficiently to develop design objects without the presence of designers. The separation of design and development is obviously one of the crucial conditions to achieve mass production that realized the wealth and the industrialized lifestyle in the 20th century, and the systematic design approach is still essential in modern industries.

2.2.2 Challenges of the systematic design approach

Next, the authors discuss challenges of the systematic design approach.
As is explained above, human factors became gradually important in design. As is shown in Figure 2, the design boundary has included more human-related elements. As a result, designers have to confront the following problems.

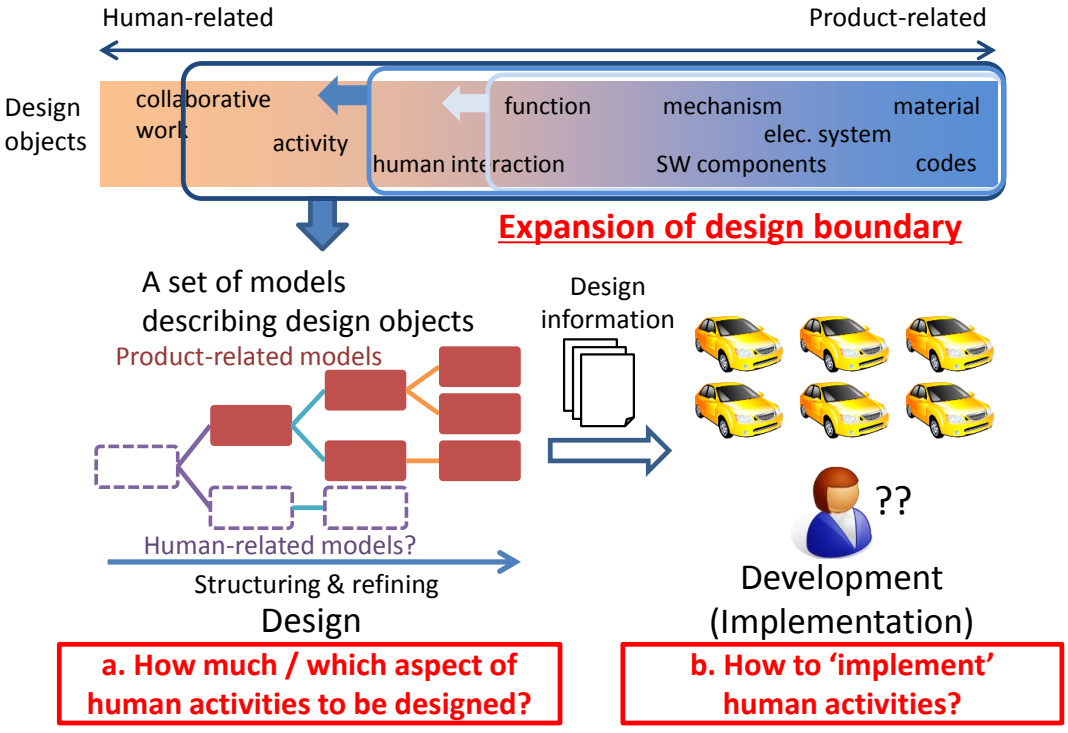

Figure 2. Challenges of the systematic design approach

- How much / which aspect of human activities to be designed?

As have been explained, many models concerning to human activities have been proposed. However, it is not easy to describe overall human activities in detail. As a similar case, the necessity and possibility of the detailed documentation of large-scale information systems has already been a long and aggressive discussion in the field of software engineering (Larman and Basili, 2003). It also requires huge cost to write down all expected human activities with various aspects and granularity. The complete description of human activities with certain models could be almost impossible. However, important aspects of human activities should be described according to the purpose of design or the characteristics of design objects. For example, when a horizontal escalator is designed, it is necessary to make a model of a pedestrian who takes or gets off the escalator to avoid the accident. Therefore, how to specify and describe them is an important issue.

- How to ‘implement’ designed human activities?

Though the design of human activities is discussed frequently, the ‘implementation’ of human activities is rarely discussed. This issue is quite difficult to solve within the scheme of the systematic design approach. It generally takes a long time and much effort for humans to learn and perform the designed activities in contrast to the implementation of logics to computers in several meanings. It is commonly known that humans have the status quo bias which causes the feeling of resistance toward the change of their activities or customs (Samuelson and Zeckhauser, 1988). In addition, humans have some variability in their behavior caused by their characteristics and motivations. These issues for implementation of human activities are rarely discussed during the design phase, though they affect the feasibility of the design result strongly.

These problems could have a strong impact on design results especially when a designer focuses more on human activities such as for service design.

3 PARTICIPATORY DESIGN APPROACH

3.1 Concept and existing methodologies

One of the promising approaches to tackle the aforementioned problems of the systematic design approach is to involve users in design activities and moreover to let them design products and implement their activities by themselves. The user involvement for design has been studied in the participatory design research and its related fields.

Participatory design is a design approach characterized by user involvement (Greenbaum and Kyng, 1991). Its origin was the study on “Collective System Design” in Scandinavia in the 70’s and 80’s (Ehn and Kyng, 1987). This study aimed at developing a system to support industrial workers by gathering their ideas broadly for the workplace democracy. Currently, participatory design is conducted typically by a small group composed by users and a researcher as a designer (van den Besselar, 1998).

There are several methodologies of participatory design and their derivatives. One of the major methodologies is based on the ethnographic study (Blomberg, et al., 1993) in a user environment. Spinuzzi (2004) has summarized the major steps of such kind of the participatory design as: (1) initial exploration of work to examine the current state of users and to determine the orientation of design by means of ethnography, (2) discovery process to understand a work organization and to envision a future workplace, (3) prototyping to fit technological artifacts into the workplace. As a derivative of such a methodology, contextual design can be taken up. Contextual design is characterized by the contextual inquiry that is an interview-based field data collection technique instead of the ordinary ethnographic study (Beyer and Holtzblatt, 1997).

Another kind of the methodologies is based on a subjective analysis by the user’s self-expression. One of the examples is cultural probes (Gaver et al., 1999). Cultural probes are a self-report package of artifacts, questionnaires and exercises that encourage users to reflect on their experience. As another example, Sunaga (2009) proposed activity-based design to let participants express themselves and their activities by sketching and acting-out that is to act their roles in a workshop. These design techniques are effective to retrieve users’ concerns and tacit knowledge.

In this study, the authors focus mainly on the design methodologies and techniques characterized by the design activity in a user environment and users’ active participation.

3.2 Features and remaining problems

The participatory design approach contains the following features concerning the aforementioned problems in the systematic design approach.

- Deep analysis on users’ concerns

In the participatory design approach, designers in the field investigate users’ actual activities and concerns. Some derivatives such as the aforementioned activity-based design encourage users even to perform subjective analysis on them and their activities. This approach is effective to specify the users’ activities to be redesigned.

- Simultaneous design and implementation of users’ activities

There are several effective techniques to redesign users' activities in the participatory design approach. For example, roleplaying games (Iacucci et al., 2000) or acting-out (Sunaga, 2009) in which they perform their roles and evaluate their activities can be considered as a simultaneous method to design and implement their activities. This approach is more efficient than implementing the activities designed by others, since users understand their ideal activities and the motivation for redesign has been already built up.

These features of the participatory design approach are effective to the aforementioned problems of the systematic design approach. However, there are still some remaining problems

- Problem 1: Cost for participants and designers

Some studies pointed out that the participatory design requires considerable cost for participants and designers who conduct the participatory design as facilitators (Spinuzzi, 2004, Pilemalm and Timpka, 2007). It might be an obstacle to the dissemination of this design approach.

- Problem 2: Discontinuity of the design activity

It is also commonly mentioned that participatory design tends to be a temporary activity and will not continue after the project ends (Spinuzzi, 2004). Another initial cost will be required for launching a new project when it becomes necessary to reform the developed product or information system in the future. In addition to the cost problem, one of the major reasons is that it would be difficult to continue design activities without facilitation of designers.

- Problem 3: Limitation of the number of participants

In the practice of participatory design, the number of participants tends to be limited into a small group (Pilemalm and Timpka, 2007). Though various approaches have been proposed to increase the number of participants such as gathering arguments from the outside of the design group (Pilemalm and Timpka, 2007) and applying a computer supported cooperative work (Perry and Sanderson, 1998), the generalization of the design result and the implementation of users' activities in a large number of group are still difficult.

- Problem 4: Lack in the formalization of users' activities

In the participatory design approach, the formalization of users' activities is not an important issue, while a set of requirements for products are considered as main results. This point is especially different from the systematic design approach. It could be a common assumption in participatory design that design information on users' activities can be shared by participants and it is not necessarily important to describe them for the future use. However, engineers who actually develop products or information systems should know users' activities correctly, especially when they design a product which requires sensitive and physical interactions such as a robot in a service field. In addition, users' concerns and knowledge on their activities acquired by participatory design tend to dissolute after the design activity has finished, and it becomes difficult to disseminate them to the people outside of the participants' group. By describing them in an explicit manner, it could be disseminated as good practices to the related work environments and it would be even reusable for the computer-supported design such as simulation of human activities to reduce the cost for trial-and-error in the participatory design approach.

To unify the systematic and participatory design approaches, the aforementioned problems should be solved.

4 TOWARD THE UNIFIED APPROACH

4.1 Requisites for the unified approach

Based on the theoretical survey, the authors suggest the following requisites to harmonize the features of two design approaches and unify them.

- Req.1: Community-based continuous improvement

To tackle the first half of the problems in the previous section, namely cost for participants and discontinuity of design activities, it would be effective to realize the continuous and efficient design cycle without the continuous participation of designers in the field. One of the promising approaches is to promote the user-driven, continuous improvement of products and activities based on a user community. Though it is difficult to eliminate the facilitation by designers especially in the phase of community development, the cost for facilitation can be lessened by realizing autonomous community-based activities. For that purpose, programs to organize a community and design support methods should be prepared. The details of design support methods will be explained later.
Such a community-based approach to improve certain activities can be seen in Total Quality Control (TQC) program (Ishikawa, 1985). The community-based approach is effective to keep the tacit information on users' activities which cannot be described with systematic models, also.

- Req.2: Modeling methodology of human activities in a systematic manner

The latter half of the problems can be tackled with the application of systematic models of human activities. The model used for the description of users' activities is determined in accordance with the users' concerns acquired through the aforementioned user-driven design approach. As have been mentioned, the complete description of human activities is almost impossible. According to the acquired users' concerns, the descriptive part of human activities can be limited. For such description of human activities, a set of systematic models of human activities including the aforementioned existing models, a modeling methodology related to the user-driven design approach and a modeling tool which users can easily use should be prepared. The modeling methodology can decrease the miscommunication between users and engineers, and help reducing the number of prototypes and the total amount of cost for participatory design. In addition, the systematic models of users' activities can be used for various engineering design support methods like the seven management and planning tool in TQC (Mizuno, 1998). For example, the activities of a large number of users can be evaluated by multi-agent simulation such as Yamashita et al. (2011). In addition, the human sensing technology based on the systematic model of human activities (for example, Pentland (2007) and Tenmoku et al. (2011)) can decrease the cost for continuous field studies. For the application of the computer-aided technology, systematic models of human activities are crucial.

Based on these requisites, the authors propose the concept of "User-driven Product/Activity Design (UPAD)" approach. The schematic view of this concept is shown in Figure 3.

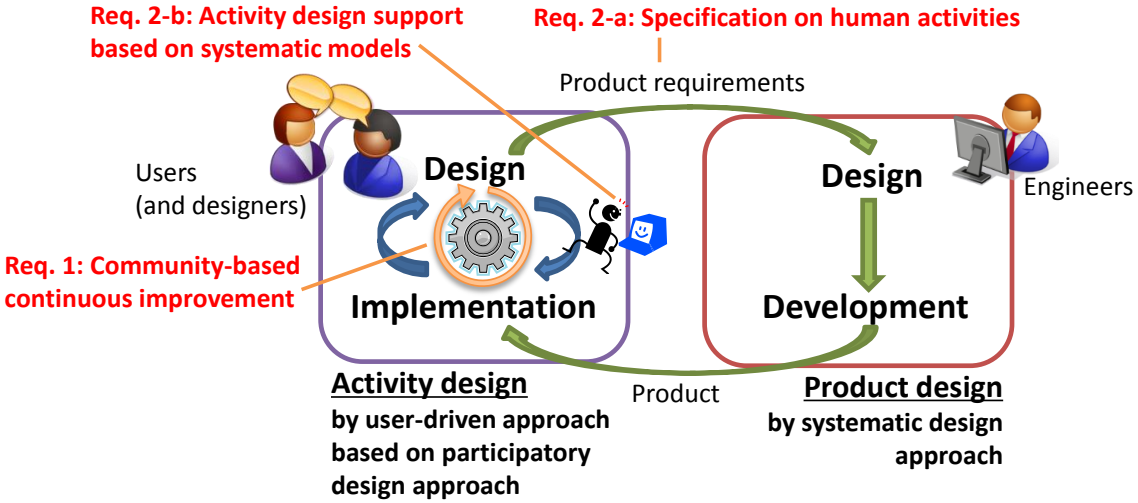

Figure 3. Overview of UPAD approach

In this approach, users' activities are designed by a user community which consists of users and designers. The user community designs and implements their activities in a user-driven manner. To understand and redesign the users' activities and products, the methodologies and techniques of the participatory design approach are applied. Requirements for products and specifications of users' activities are described with the systematic models in accordance with the modeling methodology and

tool based on the users' concerns. The modeling results of users' activities are applied to product design based on the systematic design approach and the computer support for activity design.

4.2 Research practice in a work environment

To implement the UPAD approach as a concrete methodology, the authors are actually designing and developing systems with users in several service fields. In this paper, the authors introduce a case of the nursing-care facility named 'Wakoen'. The authors have attempted to trigger the aforementioned design cycle by facilitating a user community.

1. Initial exploration

As an initial exploration, the qualitative field research was conducted in the facility first. As a result, it was clarified that the employees worked with different backgrounds and roles and they must collaborate in providing nursing-care services for various residents and patients. In addition, the service processes tended to vary dynamically depending on the states and characteristics of employees, patients and the relations among them. According to such nature of this work, there was a need for sharing information related to not only medical and physical conditions of patients but also their daily-life information for nursing-care. The fluent information sharing among employees would encourage their teamwork and improve their service quality, and even promote the trust with patients, which smoothens service processes and increases the satisfaction of patients. For this purpose, a project to design a system for information sharing and to improve service processes was launched.

2. Facilitation of a user community by using the systematic model and the quantitative data

As have been explained above, it is not easy to change employees' activities just by implementing a new information system (Nishimura et al., 2012). Therefore, the authors started with facilitating a community to improve their service processes. First, the authors conducted the time and motion study (Zheng et al., 2011), and showed the result such as the difference of workflows among employees and the inefficiency of information sharing in a quantitative manner. For the description and visualization of the result, the task classification method and the state transition model (Miwa et al., 2012) were applied. As a result, the employees started considering how to improve their service processes by themselves. Then they determined to improve the efficiency and quality of information sharing and handover to the next person in charge.

3. Prototyping

According to their discussion, the authors developed a prototype of the information sharing software for mobile devices. The user community is testing it in an actual service at each division in the facility in parallel to the continuous improvement of the prototype based on the feedback. Currently, the systematic model of users' activities has not been applied to the design and development of the system sufficiently. However, the modeling methodology to activity design and product design is being developed (Watanabe and Nishimura, 2012).

4.3 Difference from the existing methodologies

The proposed methodological concept contains some similarities with the existing methodologies. To clarify its uniqueness, the authors explain the difference among them as follows.

- Difference from agile development

The recursive design cycle of the proposed approach is relevant to agile development for system design (Larman, 2004). The advantage of the proposed approach is that it is applicable to the design and implementation of users' activities. Meanwhile, the agile development is useful when it is difficult to specify adequate users or to let them participate in design activities.

- Difference from Soft Systems Methodology

Soft Systems Methodology (Checkland and Scholes, 1990) has the similar problem setting to this study. While Soft Systems Methodology describes human activities and related information systems as a holistic system, the proposed approach attempts to promote the features of the existing design approaches and bridge the methodological gap between them.

4.4 Limitation

The proposed approach is intended to apply to the field where an organized user group exists. Business organizations such as service fields, offices and factories are considered as the most suitable application target. For consumer products with numerous users, the different approaches would be more effective.

In addition, this approach is more effective for the design of products with the high degree of technical flexibility such as information systems. Meanwhile, the rapid prototyping technology that is a fast growing category could make the application of UPAD easier for hardware design.

To clarify the applicability of the proposed approach in the aforementioned cases, the Design Research Methodology proposed by Blessing and Chakrabarti (2009) would be effective.

5 CONCLUSION

In this paper, the authors conducted the theoretical survey on the systematic design approach and the participatory design approach. As a result, it was clarified that they have a complementary relationship. For the unification of these two design approaches, the authors proposed two requisites: the community-based continuous improvement and the modeling methodology of human activities in a systematic manner. The authors proposed the concept of UPAD methodology by applying these features and introduced an attempt to embody this methodology.

In the future research, the methodology should be concretized based on the proposed concept. In particular, the process of community building, the required models and modeling methodology to describe human activities for product design and activity design, and design support methods based on them should be developed. In addition, the authors will introduce more case studies including the ongoing studies for the validation of the methodology.

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