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## Development of PSS Design Support System: Knowledge-based Design Support and Qualitative Evaluation

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### Abstract

This paper proposes methods to support PSS conceptual design. Especially, methods for supporting PSS ideas generation and evaluation are proposed. In the phase of PSS ideas generation, designers' acquisition of new design solutions is enhanced by case-based knowledge offering. The generated ideas, subsequently, are evaluated from the viewpoints of both customer satisfaction and resource constraints. In this phase, the PSS ideas are prioritized for the purpose of maximizing customer satisfaction under the constraints of resources. The effectiveness of the proposed methods is demonstrated by applying it to an example case.

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### 1. Introduction

Services are becoming increasingly important in the manufacturing industry, since a longer life or more added value of a product can be achieved by offering services combined with a product. As a result, concepts such as Product-Service System (PSS) have been attracting much attention [1, 2].

This paper proposes methods to support PSS conceptual design. Especially, methods for supporting (1) PSS ideas generation and (2) evaluation of the generated ideas are proposed. The proposed method is on the basis of the research on Japanese Service Engineering, which provides design methodology of the integrated provision of products and services [3, 4].

In the phase of PSS ideas generation, designers' acquisition of new ideas to improve current PSS is enhanced by case-based knowledge offering. Here, case-based knowledge means PSS design knowledge obtained from multiple PSS cases. The generated ideas, subsequently, are evaluated from the viewpoints of both customer satisfaction and constraints. In this phase, the PSS ideas are quantitatively prioritized for the purpose

of maximizing customer satisfaction under the constraints of resources. The effectiveness of the proposed methods is demonstrated by applying it to an example case.

### 2. Service Engineering

#### 2.1. Fundamentals of Service Engineering

The authors have carried out fundamental research on Service Engineering (SE) in Japan, which aims at providing design methodology of services from an engineering viewpoint [3, 4]. In SE, a service is defined as an activity between a service receiver and a service provider to change the state of the receiver [3]. According to our definition, a service is offered to realize the receiver's state change, and when the state changes to a new desirable one, the receiver is satisfied. Therefore, changing a receiver state is equal to fulfilling a customer need in this context. This definition includes a broader sense than the typical definitions in the service marketing field, which are used to clarify the difference between services and products (e.g., [5]). In this definition, we regard a service as a combination of

service activities and physical products [3, 4]. The term service used in this study, therefore, corresponds to PSS.

2.2. Service design methodology

Figure 1 shows the overview of service design methodology proposed in SE. It is noteworthy that a term service means a combination of service activities and physical products as mentioned above. A service is modeled as a functional structure that satisfies customer needs, and specific entities and their activities/behaviors are associated with the functional structure [3]. Here, entities include both physical products and human resources, which correspond to product share and service share in PSS context.

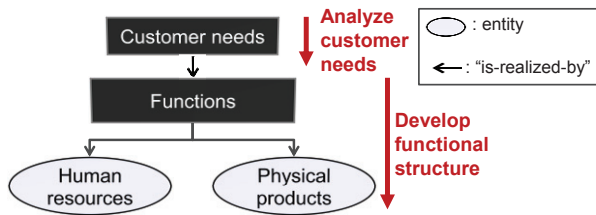


Fig. 1. Service design methodology

• Customer needs analysis

The means-end theory [6], which is proposed in the service marketing field, suggests that a consumer forms a conception of the suitability of a product or service attributes in question (means) for fulfilling specific values (end). A customer’s perception of satisfaction can be modeled by three elements: attributes, utility expectations, and values. Attributes are elements that define the quality of a product/service. Utility expectations refer to customer requirements or needs. Value indicates the goal or aim of an action.

Based on the means-end theory, a structure of customer satisfaction hierarchically modeled through three layers: quality elements, customer needs, and values/goals.

• Functional structure development

View model [3, 4] is a model to design a functional structure of a service. Figure 2 shows an example of a view model. As shown in Figure 2, this model consists of functions, which are described as “verb + noun,” e.g., “provide + maintenance,” and entities that have been used in product design methodologies (e.g., [7]).

3. PSS Conceptual Design Support

Based on literatures on PSS design (e.g., [8 - 10]), PSS design process can be described as three phases: (1) Customer analysis, (2) PSS conceptual design, and (3) PSS detailed design. In (1) Customer analysis phase,

designers collect and arrange data to specify customer needs and constraints within a service. Based on the identified customer needs, in (2) PSS conceptual design, PSS ideas are generated with, for example, brainstorming techniques. Designers then deploy each selected PSS idea to a detailed structure ((3) PSS detailed design). Here, detailed specifications of entities to realize PSS ideas are defined.

This study concentrates on the PSS conceptual design phase. The main tasks of the phase are PSS ideas generation and evaluation. The purpose of this study is to propose methods to support these two tasks.

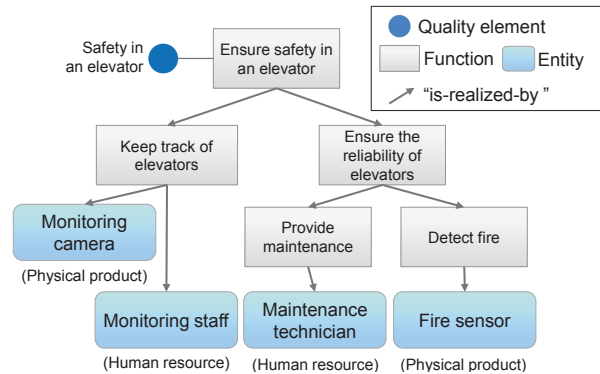


Fig. 2. An example of view model

4. PSS Ideas Generation

4.1. Approach

Analogy is a form of reasoning to obtain new knowledge. It is commonly agreed that analogy plays an important role when people acquire new knowledge [11]. In analogical reasoning, knowledge about the problem that designers have to solve (knowledge in “target” area) is obtained by copying knowledge that is directly unrelated to the problem (knowledge in “base” area) [11]. Here, knowledge in base area is associated with knowledge in target area based on the similarities between knowledge. Figure 3 shows an example of an analogy to create knowledge about a cutting knife.

In this study, the analogical reasoning is adopted as an approach to support PSS ideas generation. Figure 4 shows an overview of the proposed method. A preliminary structure of a PSS idea is described by using a concept of function like view model. Designers have to develop new functions to realize a root functions in order to make a new PSS idea.

The proposed method enables to provide candidates of new functions by copying functions stored in a database by using analogical reasoning. The reasoning is on the basis of the similarity between functions. A database includes a variety of view models already

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