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Establishment of a function embodiment knowledge base for supporting service design

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Abstract In service engineering, a service is represented as a functional structure that satisfies customer requirements. Specific entities and their activities are associated with a functional structure as a way to accomplish a goal. In this phase, it is important for service designers to have broad knowledge, since entities that construct a service include both human and physical products. Therefore, the extent of the designer's knowledge is the key to the enhancement of design solutions. However, few tools to support designers in the embodiment phase have been proposed. In this paper, for the purpose of constructing a function embodiment knowledge base in service design, the representational form of knowledge is proposed, and a prototype system of function embodiment knowledge base is established. Then function embodiment knowledge is collected from multiple service cases using the prototype system, and the effectiveness of knowledge base is discussed.

Keywords service engineering, service design, design knowledge management, embodiment, knowledge base

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1 Introduction

Recently, services have become the major factor of economic growth, especially in developed counties, and the importance of service has been emphasized in various industries. As a result, for example, product-service systems, which can create value by coupling a product and a service, have been attracting strong attention [1,2]. However, few studies have focused on the design of services. The authors, therefore, have carried out conceptual research on service engineering [3], which aims to provide engineering methodologies to design services and to develop the tools for supporting service designers, called service CAD [3,4].

In service engineering, a service is regarded as a combination of service activities and physical products. A method to design a service is proposed in a series of service engineering studies. A service is modeled as a functional structure that satisfies customer requirements, and specific entities and their activities/behaviors are associated with functional structure as a method to achieve goals [3,4]. In short, a service can be designed through phases of development of functional structures and embodiment of functions, as shown in Figure 1.

As pointed out in the product design field, knowledge obtained from past products and cases provides helpful information in the phase of embodiment [5]. Therefore, in some product design methodologies, knowledge bases to support designers in the phase of embodiment are introduced (e.g., [6,7]).

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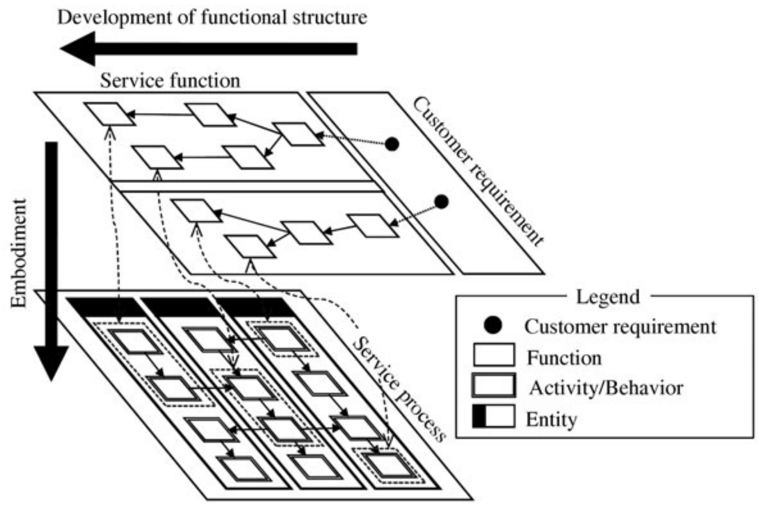


Figure 1 Approach of service design in service engineering.

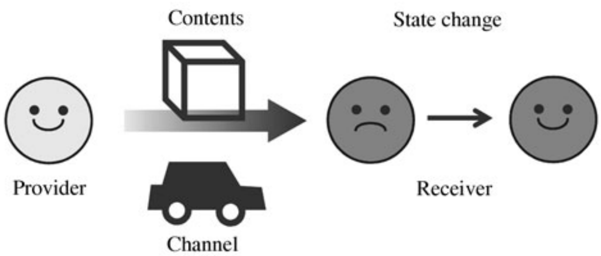


Figure 2 Definition of service.

Compared to product design, a broader range of knowledge is required in service design, since the entities used to provide services include human and physical products. For example, entities that are composed of a car-sharing service include a manager, maintenance staff, customers, cars, and maintenance tools. However, service designers have received little assistance in the embodiment phase of service design. As a result, in many cases, service design depends on designers' own experiences and knowledge. Thus, the quality of design solutions remains inadequate.

In this study, a knowledge base is established and made accessible to the service designer in the embodiment phase. To construct knowledge base, a representational form to describe and accumulate knowledge is first proposed in this paper. Then, the knowledge base is established based on the proposed representational form. The rest of this paper is organized as follows. Section 2 contains a definition and modeling methods of service, which are proposed in service engineering as fundamental concepts of this study. Section 3 is an illustration of an approach of designer support using a knowledge base. Section 4 is a definition of the representational form of knowledge regarding some requirements. In Section 5, an implemented prototype system of the knowledge base is introduced, and then established knowledge base used in case study is reported. Section 6 is a discussion of the effectiveness and future works of this research, and Section 7 is the conclusion.

2 Service design

In service engineering, a service is defined as an activity by a service provider to change the state of a service receiver [3] (Figure 2). According to this definition, a receiver is satisfied when his/her state changes to a desirable one. Since the value of a service is determined by the receiver, service should be designed to realize the preferable state change for the receiver.

In service engineering, some service models have been proposed (Figure 3).

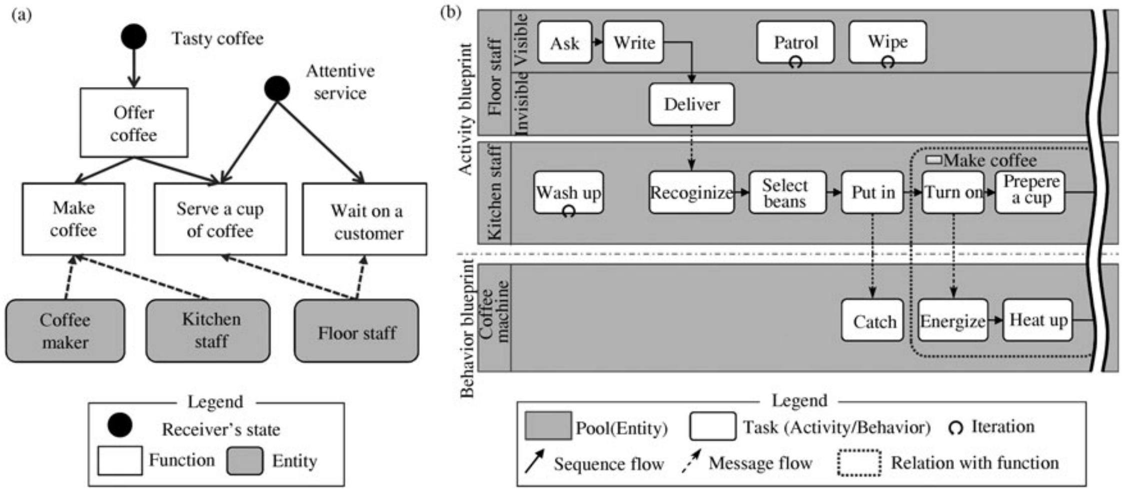


Figure 3 Models of coffee shop service. (a) Service function model; (b) service process model.

• Service function model.

Determining the way to implement changes in a receiver is most important in service design. A service function model represents the fundamental structure of the state changes of the receiver [3]. As shown in Figure 3(a), this model consists of functions, which are described as verb + noun, e.g., serve + a cup of coffee, and entities that have been used in product design methodologies (e.g., [6,7]). In this model, a preliminary function that changes the receiver's state is described and then deployed into sub-functions. Humans (e.g., staff and customers) and physical products (e.g., machines and facilities) are associated with the lowest-level functions as actual entities that realize lowest-level functions.

• Service process model.

In the marketing field, a service blueprint is the most common method used by marketers to visualize service activities in a sequential manner [8]. In service engineering, Hara et al. extended the concept of a service blueprint as a service process model that includes product behavior and its relationship to service activities as well as the connection between activities/behaviors and customer value [4] (Figure 3(b)). A service process model consists of an interrelated activity blueprint and behavior blueprint. Some activities/behaviors in the activity/behavior blueprint are related to functions in the function models. By connecting the function model and the process model, it is possible to identify what activities/behaviors of the entities realize each function.

3 Appoach in this study

This study deals with the embodiment phase and the use of a knowledge base to support service designers. Designer support in the embodiment phase is achieved with a knowledge-based service design support system, as illustrated in Figure 4.

This system includes the workspace and the design knowledge base of service designers. The design knowledge base consists of knowledge obtained from multiple cases. Moreover, a piece of knowledge is described as a set of function and its realization structure. In this paper, this type of knowledge is called function embodiment knowledge. A designer explores the desired knowledge from this knowledge base. The desired knowledge is searched for, e.g., on the basis of the similarity between functions, and is combined with the model of the design object.

4 A framework of knowledge representation

In the service marketing field, service has been studied with a focus on 3Ps: people, physical evidence, and process [9]. Additionally, Yoshikawa denotes service in terms of manifest functions that become manifest through human action or the use of artifacts [10]. These studies emphasize the importance of

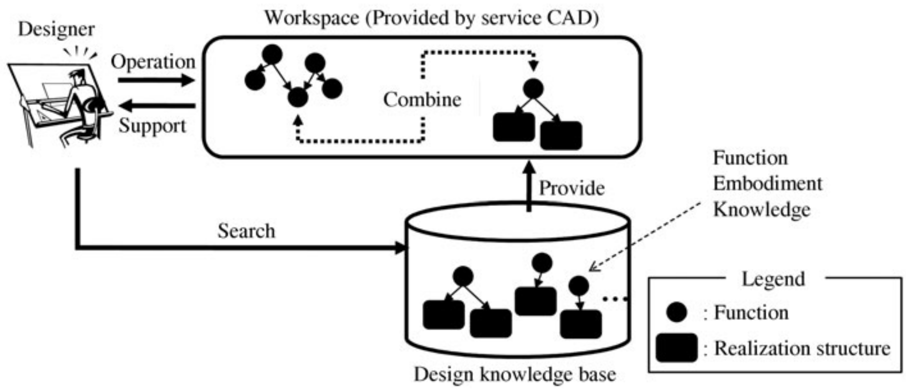


Figure 4 Approach of service designer support.

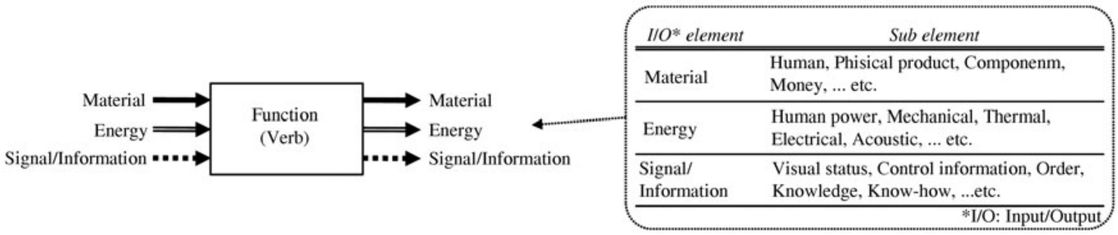


Figure 5 Input-output function representation for service design.

considering the realization processes of function as well as the entities in the embodiment phase. From these viewpoints, the function embodiment knowledge should include 2 elements: entities and realization processes.

Meanwhile, in this study, design knowledge is searched for on the basis of the similarity between functions, as reported in Section 3. In this regard, if the expression of functions is not unified, it is difficult to conduct a thorough search for the functions that have a similarity with the target function and distinguish them from those in the knowledge base [11]. Therefore, using a unified form and terms is needed for function representation to increase the reusability of knowledge and the efficiency of knowledge retrieval.

In light of these requirements, we represent a minimum unit of function embodiment knowledge by 3 elements: function (described with a unified form and vocabulary), entities, and realization processes. The remainder of this section focuses on the description of each element of knowledge.

4.1 Function

Service function represents what is offered in the service. The approaches for describing function are either verb-noun or input-output [7,11]. The verb-noun approach, which has been used in service engineering, is similar to the use of a natural language therefore more flexible and easier to be used by designers. However, this leads to a different expression of the same functions. It makes conducting knowledge difficult as stated above. Thus, this approach is unsuitable for knowledge management. On the other hand, the input-output approach that is used in various fields of design defines a function as an input-output relation among the material, energy, and signal/information (Figure 5). This approach could help to coordinate knowledge, although it confines flexibility of description [11]. For these reasons, we adopt an input-output approach to describe function in this study. Input/output elements consist of material, energy, and signal/information in a traditional way. However, service-typical elements (e.g., human, order, and knowledge) are included (see the right-hand side of Figure 5).

Furthermore, we introduce the service function vocabulary in order to normalize terms used to represent functions. The functional basis, as shown in Table 1, which was developed by Hirtz et al., organizes the verbs used in input-output function representation [12]. It includes specific functions and their synonyms in 8 categories: branch, channel, connect, control magnitude, convert, provision, signal, and support (Table 1). In our study, assuming that the functional basis is available for describing service function,

Table 1 Functional basis proposed by Hirtz et al. [12]

Class(Primary)	Secondary	Tertiary	Correspondents
Branch	Separate		Isolate, Server, Disjoin
		Divide	Detach, Isolate, Release, Sort
		Extract	Refine, Filter, Purify, Percolate, Strain, Clear
		Remove	Cut, Drill, Lathe, Polish, Sand
	Distribute		Diffuse, Dispel, Disperse, Dissipate, Diverge, Scatter
Channel	Import		Form entrance, Allow, Input, Capture
	Export		Dispose, Eject, Emit, Empty, Remove, Destroy, Eliminate
	Transfer		Carry, Deliver
		Transport	Advance, Lift, Move
		Transmit	Conduct, Convey
	Guide		Direct, Shift, Steer, Straighten, Switch
		Translate	Move, Relocate
		Rotate	Spin, Turn
		Allow DOF	Constrain, Unfasten, Unlock
Connect	Couple		Associate, Connect
		Join	Assemble, Fasten
		Link	Attach
	Mix		Add, Blend, Coalesce, Combine, Pack
Convert			Condense, Create, Decode, Differentiate, Digitize, Encode, Evaporate, Generate, Integrate, Liquefy, Solidify, Transform
Provision	Store		Accumulate
		Contain	Capture, Enclose
		Collect	Absorb, Consume, Fill, Reserve
	Supply		Provide, Replenish, Retrieve
Control Magnitude	Actuate		Enable, Initiate, Start, Turn-on
	Regulate		Control, Equalize, Limit, Maintain
		Increase	Allow, Open
		Decrease	Clise, Delay, Interrupt
	Change		Adjust, Modulate, Clear, Demodulate, Invert, Normalize, Rectify, Reset, Scale, Vary, Modify
		Increment	Amplify, Enhance, Magnify, Multiply
		Decrement	Attenuate, Dampen, Reduce
		Shape	Compact, Compress, Crush, Pierce, Deform, Form
		Condition	Prepare, Adapt, Treat
	Stop		End, Halt, Pause, Interrupt, Restrain
		Prevent	Disable, Turn-off
		Inhibit	Shield, Insulate, Protect, Resist
Signal	Sense		Feel, Determine
		Detect	Discern, Perceive, Recognize
		Measure	Identify, Locate
	Indicate		Announce, Show, Denote, Record, Register
		Track	Mark, Time
		Display	Emit, Expose, Select
	Process		Compare, Calculate, Check
Support	Stabilize		Steady
	Secure		Constrain, Hold, Place, Fix
	Position		Align, Locate, Orient

we use this vocabulary to describe service functions.

In summary, a unified representation of function is realized by using the input-output approach in combination with the service function vocabulary in this study. In other words, a function in knowledge is described by 3 elements: input, output elements (material, energy, and signal/information), and a verb (from the vocabulary).

4.2 Entity

Entity means human and physical resources that construct a service, e.g., staff, machinery, and facility. As discussed in Ergonomics (e.g. [13]), humans and physical products have some differences in their features; for instance, flexibility of communication, variety of performance, tiredness, etc. Thus, it is essential that service designers select appropriate entities for each function of a service, taking into consideration the different features of humans and products.

In this study, therefore, not only a name of entity but also a type of it are clearly described in function embodiment knowledge, because they become one of guideposts when designers select the entities.

4.3 Process

A service delivery process is a series of tasks that provide value to customers. Namely, service delivery process represents how to provide functions or values.

In this study, knowledge concerning service delivery process is described in the form of the service process model reported in Section 2. This is because a process knowledge represented with this form can be understood easily without specialized knowledge [4]. This intelligible form is appropriate for knowledge-based design support for the following two reasons:

• General representation form that does not depend on a specific domain.

Service includes a wide variety of corporate activities. It is therefore supposed that function embodiment knowledge apply to various domains. Consequently, a general representation form that does not depend on a specific domain is appropriate and useful.

• Various participants in service design.

To design services, various departments need to participate in design cooperatively. It is desired that all participants, e.g., managers, staff, and IT experts, understand and use function embodiment knowledge in a common manner.

In this study, a process in knowledge is described as activities/behaviors in part of a service process model.

4.4 Proposal summary

As reported in this section, the function embodiment knowledge is represented by 3 elements: function, entities, and realization processes. Namely, the knowledge is represented and collected in the form shown in Table 2. Entities and their activities/behaviors are accumulated with the service function manifested by them. This enables service designers to refer to the realization structures based on the similarity between functions.

5 Implementation and verification

5.1 Implementation of a knowledge editor

We implement a prototype of knowledge editor to Service Explorer Xi[4], which is a CAD system for design services developed by authors using an Eclipse Rich Client Platform[14]. This implemented editor enables users to describe, accumulate, and display the function embodiment knowledge based on the proposed representation form (shown in Table 2). Figures 6 shows some examples of the execution screen. Figure 6(a) shows the screen shots in the process of editing a function with the input-output approach. Each input/output element and function vocabulary is implemented by this editor, so users must only select

Table 2 The framework of function embodiment knowledge

Items		Contents
Function	Input Elements	Material, Energy, or Signal/Information
	Function	Verb (from the Vocabulary)
	Output Elements	Material, Energy, or Signal/Information
Realiztion structure	Entities	Entity name, Type (Human or Physical product)
	Processes	Activities/Behaviors

(a)

(b)

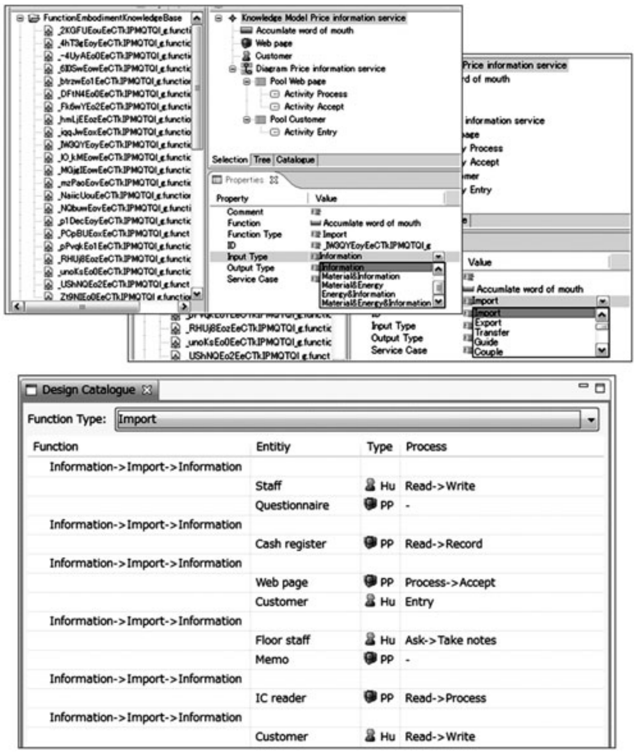


Figure 6 Screen shots of implemented system. (a) Knowledge editor; (b) knowledge viewer.

the terms to convert function representation. Figure 6(b) displays the accumulated knowledge in a list format, such as a catalogue.

5.2 Constructing a function embodiment knowledge base from service cases

To construct the service design knowledge base used in the embodiment phase, we acquired function embodiment knowledge from 20 service cases. The service cases were selected from a collection of high-valued service cases [15] on the basis of the Lovelocks' service classification approach [9], which is broadly used in the service marketing field.

These service cases were represented by function model and process model. Then, a relation among the lowest functions, entities, and their activities/behaviors was detected. Following this relation, function embodiment knowledge was described and accumulated using the implemented editor. In this step, however, the functions were described by the verb-noun approach. To unify the expression of functions, it is necessary to convert the representation of functions into an input-output approach. Referring to the input/output elements and function vocabulary implemented in the knowledge editor, the conversion was executed.

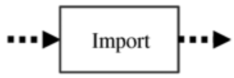
According to the above procedure, we constructed a prototype of knowledge base from these 20 service cases. A part of the accumulated knowledge is shown in Table 3.

Table 3 A part of the constructed knowledge base

No.	Functional structure			Realiztion Structure			(Reference)
	Input	Function	Output	Entity	Type	Process	
1	I (Request)	Change	I (Way to destination)	Driver	H(Prv.)	Ask→Operate	Taxi
				Car navigation system	PP(Prv.)	Import→Search→Display	
...	...	...	...	...	...	...	...
14	I (Condition of sushi)	Sense	I (Condition of sushi)	IC tag	PP(Prv.)	Emit	Sushi-go-round
				Info.management system	PP(Prv.)	Read→Search→Specify→Analyze	
15	I (Condition of a patient)	Sense	I (Symptom)	Doctor	H(Prv.)	Ask→Diagnose→Analyze	Medical service
16	I (Condition of floor)	Sense	I (Condition of floor)	Cleaning staff	H(Prv.)	Watch→Search	Hotel
...	...	...	...	...	...	...	
30	I (Order)	Import	I (Order)	Floor staff	H(Prv.)	Ask→Write	Coffee shop
				Memo	PP(Prv.)	–	
31	I (Order)	Import	I (Order)	Touch-panel device	PP(Prv.)	Detect pressure→Process→Send	Sushi-go-round
32	I (Customer Info.)	Import	I (Customer Info.)	Info. reader	PP(Prv.)	Read→Record	Supermarket
33	I (Request)	Import	I (Request)	Telephone Operator	H(Prv.)	Grab→Greet→Ask	Taxi
				Phone	PP(Prv.)	Ring→Translate signals→Send	
34	I (Comments)	Import	I (Comments)	Customer	H(C)	Entry	Mail-order shop
				Web page	PP(Prv.)	Process→Accept	
35	I(Experience)	Import	I(Experience)	Clerk	H(Prv.)	Read→Write	Hotel
				Questionnaire	PP(Prv.)	–	
36	E (Acoustic E.)	Regulate	E(Acoustic E.)	Audio equipment	PP(Prv.)	Read→Replay	Movie theater
37	E (Acoustic E.)	Regulate	E (Acoustic E.)	Staff	H(Prv.)	Ask→Sing	Nursery
38	E(Acoustic E.)	Regulate	E(Acoustic E.)	Pianist	H(Prv.)	Read score→Play	Hotel
...	...	...	...	...	...	...	
52	I (Patient's data)	Supply	I (Patient's data)	Electronic medical chart	PP(Prv.)	Display	Medical service
53	I (Knowledge)	Supply	I (Knowledge)	Educational staff	H(Prv.)	Explain→Answer→Explain	Call center
54	I (Info. about parts to check)	Supply	I(Info. about parts to check)	Check list	PP(Prv.)	–	Gas station
...	...	...	...	...	...	...	
73	M (A cup of coffee)	Transfer	M (A cup of coffee)	Floor staff	H(Prv.)	Grab→Walk→Put on	Coffee shop
74	M(Dishes with stale sushi)	Transfer	M (Dishes with stale sushi)	Automatic conveyor-belt	PP(Prv.)	Move to one direction	Sushi-go-round
75	M (Items)	Transfer	M (Items)	Floor staff	H(Prv.)	Put items in→Push→Walk	Supermarket
				Cart	PP(Prv.)	Spin wheels	
76	M (Foods)	Transfer	M (Foods)	Driver	H(Prv.)	Put items in→Drive	Food distribution
				Car	PP(Prv.)	Spin wheels	
...	...	...	...	...	...	...	

M: Material; E: Energy; I: Information/Signal; H: Human; PP: Physical product; C: Customer; Prv.: Provider; (Ex.) "H(Prv.)" means the entity is a Human, who is a part of the service provider.

Table 4 The translation results of function representation

Input-output approach	Verb-noun approach	Reference
	Serve a cup of coffee	Coffee shop service
	Carry sushi on dish	Sushi-go-round service
	Carry items	Supermarket
	Deliver foods	Food distribution service
	Find old(/stale) sushi	Sushi-go-round service
	Diagnose illness	Medical service
	Inspect a car	Gas station service

: Material : Signal/Information

6 Discussion

6.1 Effectiveness of this study

1) Unifying representation of service function.

Table 3 shows a variety of function embodiment knowledge arranged according to a similary of each function. For example, Nos. 73–76 show the knowledge that includes the function transport material. In the verb-noun approach, these functions were described by different expressions, e.g., serve a cup of coffee, carry sushi on dish, carry items, and deliver foods (Table 4).

This result shows that it is effective to adopt the input-output approach and the service function vocabulary to unify the expression. Furthermore, the unified expression of function helps a designer to search the desired knowledge efficiently.

For example, in a case where we have applied the proposed knowledge base to an accommodation service design, a designer could refer to several kinds of ideas to realize a service function. In this case, firstly, a service function model to realize a receivers' state comfort in the hotel was constructed. Then, a function control ambient sound was described as one of the lowest-level functions in the service function model. The function could be represented as regulate energy (acoustic energy) in the form of input-output function. By using the proposed knowledge base, knowledge including a function regulate energy (Nos. 36–38 in Table 3) was offered to the designer; then, the designer could generate some idea to realize this function: installation of audio equipment to replay CDs and employment of a pianist or singer to provide live sound BGM.

Generally, to enhance the quality of design solutions, a designer is desired to have many candidates of realization structure for each function in the embodiment phase [5,6]. This study contributes to the enhancement of the quality of design solutions, since it could help increase the number of candidates by providing several ideas to designers.

2) Comparison with related works.

The ontology-based knowledge management has been proposed in some service design researches (e.g., [16,17]). These researches tackle to define generic structures of service design elements for the purpose of achieving efficient design knowledge management. However, these researches have not yet provided knowledge-based design support methods and tools based on the ontology.

In contrast, this study concentrates on supporting designers in the specific phase of service design procedure, and provides a tool to support designers. In addition, the proposed knowledge base manages both service share (human and his/her activities) and product share (physical product and its behaviors) on the basis of a common viewpoint what types of function is become manifest by them. The viewpoint of function is very important in the fields of design [5,6], although the studies on service ontology do not consider it.

6.2 Remaining issues and future works

1) Need for computational knowledge retrieval.

In this study, the representational form of function embodiment knowledge is defined. In addition, the prototype of the knowledge editor is implemented. This makes it possible to describe, accumulate, and display function embodiment knowledge in a computer. However, intelligent design support, which means automatically retrieving or eliciting acceptable knowledge, is not achieved. As the volume of knowledge expands, the burden of knowledge retrieval for a designer increases. To solve this issue, a knowledge search engine must be implemented to the design support system.

2) Decrease in burdens on acquisition of an immense amount of knowledge.

The amount of knowledge is the key determinant in the effectiveness of design support using the knowledge-based system. As reported in Section 5, the design knowledge base including a knowledge editor is implemented in this study. Designers acquire knowledge from, e.g., books, news, or Web, and translate it into function embodiment knowledge using the knowledge editor; then the knowledge is accumulated in the knowledge base. This process put a burden on designers when the amount of knowledge is immense.

To solve such problem, recently, the research on web-based knowledge acquisition attracts attention [18]. One of the authors of this paper is developing a system to acquire knowledge automatically from Web resources [19]. This system automatically acquires press release articles from the Web and extracts specific design knowledge from them. This system helps designers to acquire an immense amount of knowledge and construct a large-scale knowledge base.

However, the trade-off problem between quality and population of knowledge base is pointed out [19]. The knowledge acquired from Web resources includes not only very fruitful information but also a lot of fruitless information. It will cause a decrease in reliability and reusability of knowledge. Therefore, future researches will include the integration of the developed knowledge base and this automatic knowledge acquisition system considering the optimal balance between the amount and the reliability of knowledge.

7 Conclusion

In this paper, we focus on the importance of service design support in the phase of embodiment. We define the representational form of function embodiment knowledge in service design. As a part of the designer support system, the prototype of a knowledge editor to construct a knowledge base was implemented. Plenty of function embodiment knowledge was accumulated from a variety of service cases with the implemented knowledge editor. From the result of knowledge accumulation, we discuss the effectiveness and the remaining issues of this study.

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