Deliberation of value-sympathy model for adaptive service attendant system

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***Abstract*— For service engineering, a mathematical model of customers is indispensability. This paper presents a design procedure of the service value-sympathy model by utilizing Self-Organizing Map (SOM) to establish a formulation of the model implementable to the service devices. The model is expressed as a mapping function of SOM computed using the questionnaire data on the service recipients, and the questionnaire is designed using results of the qualitative analysis to the service providers. The effectiveness of the design procedure and the modeling method were verified through the case-study of the hotel reception service. Predicting the guest satisfaction using the obtained value-sympathy model, an accuracy of the model and its feasibilities were investigated. Although the matching ratio in the cross-validation was not sufficiently high, a direction to create a new value concerning the service engineering could be shown.**

I. INTRODUCTION

Present export-driven basic industries, such as automobile, semiconductor, and home electronics, are getting not to be adaptable to recent diversification of consumer needs. This tendency is remarkable in Japan [1], and the creation of new industrial system and its realization are expected in order to meet the consumer needs. In short, with consideration of two axes of 'adaptability to individual needs' and of 'creation of new values', companies have to exploit new sustainable and viable industry. One of candidates involving these two axes is the service industry. Since the purpose of the service is to cater to individual requests, it possesses great potential to create new values. Actually, the service industry holds an important position in the economy, and ratio of the service in GDP in advanced countries reaches 70 percent [2]. In the IT field, it is said that the service industry accounts for 80 percent of the global economy. Recently, efforts toward the service business not only in the IT field but also in the manufacturing industry increase; hence, a cross-section study and a systematization concerning its theory and application are required.

Because of this situation, a concept of *Service Engineering* was presented in 2002 from Research into Artifacts, Center for Engineering, The University of Tokyo [3]. Service engineering is a new discipline to develop service scientifically by utilizing engineering, psychology, information-technology, and economics. The aim is an establishment of the mathematical service models and of a design theory to provide service using artificial systems. Also from a business community, SSME (Service Science, Management, Engineering) was proposed by IBM as the next frontier in innovation, and Service Innovations Symposium for 21st century was held in 2004 [4]. As just described, action researches for systematism of a service discipline are promoted.

Service itself is, however, difficult to deal with due to its ambiguous characteristics such as intangibility, simultaneity, heterogeneity, and perishability [5]. Since a service is also invisible and directly undetectable, any service providers behave based on their own experience and intuition even if some service manuals are prepared. It is difficult for even human to provide a service uniformly for any service recipients. Therefore, if some machine can measure the service quality quantitatively and correctly at the moment of the service encounter, a service will be provided adequately to any type of recipients. And if some model for the service axiom can be established using the measured data with sensor application and actuator technologies, it is expected that a design method to build a service attendant system will be established. Based on above-mentioned idea, a concept named *Adaptive Service Attendant* (ASA) was proposed and has been studied in a feasibility study under Service Science, Solution and Foundation Integrated Research Program (S^3FIRE) supported by the Japan Science and Technology Agency (Project leader: Hajime Asama). Under the project, *service physiology* and *value-sympathy model* are studied as ones of the key components.

Fig. 1. (A) Service encounter at the hotel reception, (B) Guide robot as an example of ASA

Various types of the service model have been presented,

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and social research methods such as the marketing analysis and the customer value analysis are established. Those are, however, so-called management strategy models, and are not adequate to be used as the value-sympathy model for the ASA system. Because such existing service models are qualitative that can be utilized by human analysts, and are not quantitative mathematical model that can be implementable for the ASA machine. Hence, in the present study, the following agendas are addressed using Self-Organizing Map (SOM) to build the mathematical value-sympathy model.

- Suggestion of the value-sympathy model expression
- Suggestion of a design procedure of the modeling
- Verification of the modeling and its procedure

Main purpose of the present feasibility study is a verification of the presented concept and procedures. Feature of the present study is a demonstration using a case-study of the hotel reception service based on the web questionnaire.

The latter sections are organized as follows: In Section II, the concept and formulation for the value-sympathy model are presented. The design procedure to obtain the model is explained in Section III. Section IV describes the details of the procedure by applying it to the hotel reception service. Section V is a discussion for future work, and Section VI presents the conclusion.

II. Formulation of value-sympathy model

Minimum elements to model a service encounter are a service provider and a service recipient. A service can be thought as a certain interaction factor between the provider and the recipient. Since the provider can decide contents of the service, a service can be considered as a manipulatable input. Therefore, assuming conceptually that the provider, the recipient, and the service are expressed by functions $f(), g()$, and variable u, respectively, a diagram shown in Fig. 2 can be thought. The recipient, which is represented by a yellow region in the figure, owns an internal status x, outputs the behavior y according to the received service u, and changes the satisfactory degree J. The recipient model can be expressed as a function that changes the attitude-satisfaction depending on the internal status. Subscript j for $f()$ indicates difference of recipients. On the other hand, the provider (represented by a blue region) has various recipient models as his/her knowledge-experience, and generates adequate service u according to the recipients' type using an inverse model $f^{-1}()$. Individual difference is expressed as a difference of $f_j() - f_{j+1}()$, and the provider deals with the recipients' difference.

Developing the diagram shown in Fig. 2 into a block diagram to obtain a model implementable to ASA, Fig. 3 can be considered. The upper and lower blocks express the service recipient and the provider, respectively. The recipient can be considered as a controlled plant $f()$ of which input is a service u and of which output is behavior y. Internal status x, for instance, consists of the experience (x_x), demand (x_d), and personality (x_p), and then x is described as $x := [x_x^T,\ x_d^T,\ x_p^T]^T$. On the other hand, the provider can be thought as a controller that includes an inverse model of

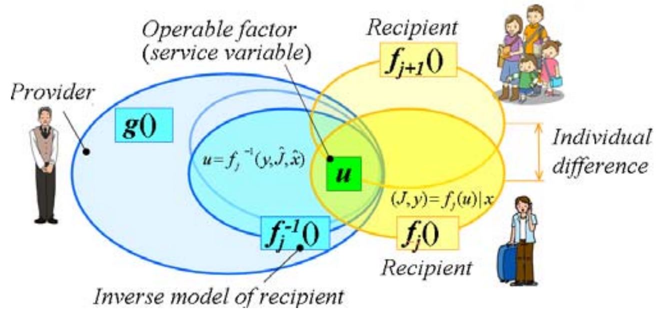

Fig. 2. Relation between service provider and recipient.

the recipients to estimate the internal status of the recipient ($\hat{x}$ and $\hat{J}$) from the behavior, and decides the service to maximize the recipients' satisfaction J.

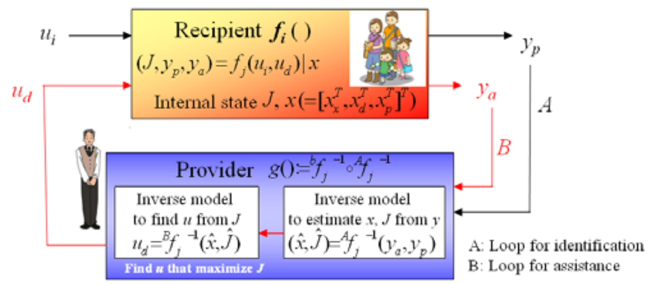

Fig. 3. Block diagram of service communication.

Considering the properties of the service encounter, it is preferable to divide the service variable u into two types: a direct service u_d given interactively by the provider and an indirect service u_i provided from atmosphere of the encountering place, i.e., $u := [u_i^T,\ u_d^T]^T$. Similarly, the behavior of the recipient, y, is divided into two types: a passive information y_p such as an appearance and an active one y_a such as spoken language, and $y := [y_p^T,\ y_a^T]^T$. Including these variables, whole variables required for the value-sympathy model are summarized in Table I. The first step to build the value-sympathy model of the service provider is an identification of the function ${}^Af_j^{-1}$ shown in Fig. 3 by using variables that are indicated in the table. And the second step is a design of an optimizer function ${}^Bf_j^{-1}$ to search the service maximizing customer satisfaction. This paper focuses on the first identification issue.

III. Procedure to design the value-sympathy model

To actually build a value-sympathy model, the following works are required: extracting the service factors that reflect characteristics of the target service, understanding the causality among the extracted factors, assigning the factors to variables defined in Table I, and acquiring numerical data corresponding to those variables. The design procedure involving these works is illustrated in Fig. 4. Below are the reasons and details of each step in the presented procedure.

TABLE I

DEFINITION OF VARIABLES FOR VALUE-SYMPATHY MODEL.

Variables and its meaning		
Observation information (A)	y_p	Passive factors (skin color, clothes, facial expression, behavior, ...)
	y_a	Active factors (greeting, spoken language, response, ...)
	u_i	Indirect factor such as environmental conditions (climate, events, time zone, ...)
Internal information of recipient (B)	x_x	Experience
	x_d	Demands (purpose, intention, ...)
	x_p	Personal information (nationality, race, ...)
Information required for the clustering (C)	u_d	Direct assistant by provider for recipients
	J	Satisfaction (evaluation by recipients)

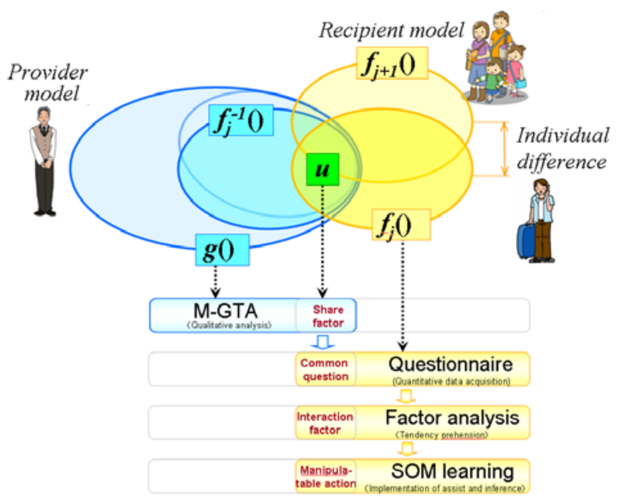

Fig. 4. Value-sympathy model and its design procedure.

Step 1: Qualitative analysis
Since various factors such as experience, intuition, and others relate each other to proffer service, these factors have to be clarified. And it is necessary to specify a range of the service variables that are manipulatable by the provider. These informations are so-called implicit knowledge, and it is required to unearth them from the providers' empirical rules and comprehension mastered through his/her experience. Therefore qualitative structure concerning the target service is clarified with the social inquiry approaches such as the interview analysis, the observational investigation, and the modified grounded theory approach (M-GTA) [6], [7].

Step 2: Quantitative data acquisition
The service recipient evaluates a service given by the provider, and his/her evaluation is strongly affected by his/her own cultural and psychological background. To know the mutual relation concerning the personal characteristics, it is necessary to collect data from a certain amount of recipients. Therefore, quantitative data are obtained with a questionnaire and/or the psychological scale composing method in this Step 2. Question items in the survey method are made so as to measure the service factors that were confirmed via the qualitative analysis of the service providers as mentioned in Step 1. In other words, these items are prepared by considering how the recipient will behave against the service given from the provider. This step is required to obtain the information which corresponds to y_a and J against u_d.

Step 3: Factor analysis
This step is a pre-processing to adjust conditions for the SOM training in the following Step 4. First, variables shown in a list of Table I are assigned to each question items. Second, the factor analysis is performed to the question items, and dominant factors and the weight coefficients are computed. Last, the dimension of the input data for the following SOM training is reduced by introducing new variables computed by the weighted summation of dominant factors. In reality, an importance of this Step 3 had been found after trial-and-error to derive the design procedure. Details of Step 3 is mentioned in Section IV-D.

Step 4: SOM modeling
Answers to each question item are converted to be adequate for the SOM training: a displacement to numerical data from choices, a dimensional reduction of the input vector, and a normalization of the numerical data. The reduction was performed by integrating multiple answer into one variables with a binary-to-decimal conversion. The normalization was executed to decrease computational error caused by different ranges of numbers in components of the input vector. Each component was normalized into the $[0, 1]$ range by using the maximum and minimum values of each component. The input vector $\mathbf{x}$ is specified as $\mathbf{x} := [y_p^T, y_a^T, x_x^T, x_d^T, x_p^T, u_i^T, u_d^T, J^T]^T$ by combining each component, and a set of the input-vector for the SOM training, $\{\mathbf{x}\} \in [0, 1]^{n \times N'}$, is prepared by concatenating a certain amount of sampling data, where n is a size of the input vector and N' is the amount of sample data.

In this study, a popular two-dimensional SOM (2D-SOM) was utilized since a planar rectangular map is preferable to avoid an isotropic alignment of reference vectors [8]. 2D-SOM is defined as a grid map (the map size is denoted as $u \times v, L := u \cdot v$), and each intersection point (node) of the grid is associated with a weight vector (reference vector) of the same dimension as the input vector. At training of the SOM, the reference vectors around the best-matching node (BMN) are updated selectively after finding the BMN of which reference vector is closest to given input vector. The update computation is described as

$$m_k(t+1) = m_k(t) \cdot h(t)\ [\mathbf{x}(t) - m_k(t)], \tag{1}$$

where t is a counter for the repetitive computation, and $m_k \in R^{n \times 1}$ $(k = 1, \cdots, L)$ is a reference vector associated with k th node. $h(t)$ is a kernel function and decides the region of the updating and its update rate. The closer node is to the BMN, the larger $h(t)$ gives rate. The node index of the BMN is found by

$$c = arg \min_k \{\|\mathbf{x} - m_k\|\} \quad k = 1, \cdots, L. \tag{2}$$

After the training of the SOM by using Eqs.(1)(2) with a set of input data of the service recipients' answer $\{x\}$

has finished, recipients types are classified according to their characteristics, and 2D-SOM map that preserves the topological properties of the input space can be obtained. The obtained map (in a precise sense, trained reference vectors) is utilized as a master form as a mapping function $f()$ for the recipient value-sympathy model. The following section explains the detail of each design step through the case-study of a hotel reception service.

IV. Value-Sympathy Model of Hotel Reception Service

Since reception service is one of preliminary service activities to provide main service and is an intervening variable of service quality, it is a significant factor [9]. For instance, a reception service at the hotel is an intervening service against the main service to provide a place to sleep. A reception service is established by communication between the service provider and the recipient. The provider attends to each recipient's request using available methods and has to communicate with the recipient so as to maximize recipient's satisfaction. Manipulatable communication variables the reception service are finite, and therefore, this situation is adequate for a feasibility study. Hence, a hotel reception service was adopted here as a case-study.

A. Qualitative analysis (Step1)

We interviewed several hotel staffs, observed their treatment for customers, and investigated their action using an ethnography method. And a qualitative analysis of the hotel reception service was performed using M-GTA. With the help of Royal Park Hotel (Kanagawa, Japan) and Kobe Portopia Hotel (Hyougo, Japan), we interviewed three reception staffs, two doormen, and two restaurant staffs, and asked how they treated guests and what the good service was. As a result, it was confirmed that a communication with customers was recognized as a manipulatable factor. And the following unique stance as a hotel staff were found: to treat each person as a special guest, to propose proactively something beyond the guest's request, and to behave in a casual manner rather than in a formal way. These knowledge were taken into consideration at the following step to prepare question items.

B. Quantitative data acquisition (Step 2)

Examples of question items made by considering the result of former qualitative analysis are shown in the first column in Table II. The choices corresponding to each item are denoted in the third and the later columns. By considering the frequency in use and an utilization purpose, the number of sample was decided as shown in Table III. Web questionnaire was conducted to persons who had stayed in the past one year through an investigation firm. Valid response from 310 persons could be received (Male 72.6%, Female 27.4%).

C. SOM modeling (Step4)

(For convenience of the explanation, this Step 4 is mentioned before Step 3.) The questionnaire items that seem

TABLE II

QUESTION ITEMS OF QUESTIONNAIRE TO HOTEL GUESTS.

Screaning questions	Variables	Choices 1	2	3	4	5	6	7	8	9	10	11	12
SQ1: Gender?	x_c	Male	Female										
SQ2: How old are you?	x_c	~10	20~24	25~29	30~34	35~39	40~44	45~49	50~54	55~59	60~64	65~69	over 70
SQ4: How often did you utilize accommodations for business purposes in the last twelve months?	x_x	many times in a month	a few times in a month	a few times in a half year	a few times in a year	one time in a year	few						
SQ5: How often did you utilize accommodations privately in the last twelve months?	x_x	many times in a month	a few times in a month	a few times in a half year	a few times in a year	one time in a year	few						
Type of accommodation where you stayed	Variables	1	2	3	4	5	6	7	8	9	10	11	
Q1: What type of accommodation did you stay for domestic trip in the last year? (please select all that apply)	x_x	Business hotel	City hotel	Resoart hotel	Inn	Guest house	Pension	Bathhouse	Recreation facility	People's hotel facilities	Other	I had no trip	
Q2: What type of accommodation did you stay for foreign trip in the last year? (please select all that apply)	x_x	Business hotel	City hotel	Resoart hotel	Guest house	Pension	Other	I had no trip					
The most memorable experience of stay	Variables	1	2	3	4	5	6	7	8	9	10		
Q3: When did you experience it in domestic trip or in foreign trip?	x_x	Domestic	Foreign										
Q3-3B: What type of accommodation did you stay at that time?	x_x	Business hotel	City hotel	Resoart hotel	Japanese inn	Inn	Pension	Bathhouse	Recreation facility	People's hotel facilities	Others		
Q3-5: What was the purpose of the stay?	x_d	Sightseeing	Tour	Class trip	Wedding	Business trip	Aniversay	For other event	Others				
Q3-6: Whom did you stay there with?	x_d	Alone	With someone	With family	With friends	With tour guests	Others						
Level of satisfaction to that accommodation	Variables	1	2	3	4	5	6	7	8	9	10		
Q4-5: How much did you expect to the service at that accommodation before stay?	x_d	1(low)	2	3	4	5	6	7	8	9	10 (high)		
Q4-6: How much did you expect before stay that the hotel staff answer to your private request?	x_d	1(low)	2	3	4	5	6	7	8	9	10 (high)		
Q4-7: How much did you worry before stay about inconvenient events during the stay?	x_d	1(low)	2	3	4	5	6	7	8	9	10 (high)		
Q4-14: Do you want to utilize that accommodation frequently from now on?	J_1	1(low)	2	3	4	5	6	7	8	9	10 (high)		
Q4-16: Do you want to keep utilizing that accommodation from now on?	J_2	1(low)	2	3	4	5	6	7	8	9	10 (high)		
Q4-17: Will you choose that accommodation as first candidate for next time?	J_3	1(low)	2	3	4	5	6	7	8	9	10 (high)		

to be important were selected and were assigned to any of variables shown in Table I. An example of the assignment was shown in the second column in Tabel II. As a result, 33 items were chosen as service variables, and total 302 samples were obtained after preprocessing mentioned in Section III. The SOM was trained by utilizing SOM_PAK [10] using the 302 input vectors. A 2D hexagonal lattice was chosen for the grid map. The grid size was decided as $u = 750$ and $v = 100$ in proportion to the ratio of the first and second maximum eigen-values of the covariance matrix of the input vector set [8]. A bubble type neighborhood kernel function was selected for the SOM training. In the SOM-training process, a fine tuned training was repeated after a rough tuned one was computed. Their training rates & update radius were specified as 0.05 & 150 and 0.02 & 50, respectively. These two training phases were repeated 20,000 and one million times, respectively. It is known that

TABLE III

ALLOCATION OF SAMPLES FOR HOTEL SERVICE QUESTIONNAIRE.

	Frequencies of private use	
Frequencies of business use	High	Low
High (more than once in a half year)	75 samples	75 samples
Low (less than once in a year)	75 samples	85 samples

training amount is preferable to be more than 500 times of the number of nodes [11], and the above case requires 750 x 100 x 500 = 35 million. However, we quit the training at one million time since it was confirmed by checking the transition of the training error that the training was almost finished after one million iteration. It took about 250 minutes by using a Windows 7 PC (with 2.8 GHz Intel Core i7 CPU [8 core] with 16GB memory) for the two step computations. U-matrix [12] visualization of the obtained SOM map is shown in Fig. 5. It can be found that obvious clusters were formed.

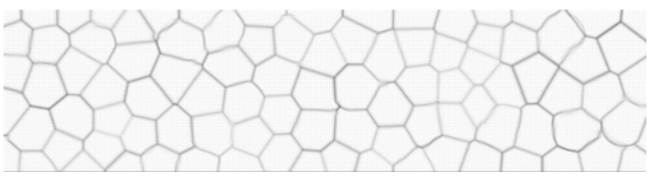

Fig. 5. SOM classifying types of hotel guest.

D. Verification and improvement (Step 3)

By estimating satisfaction using the trained SOM from the information not including the satisfaction indexes, an accuracy of the obtained value-sympathy model was investigated. The estimation was readily performed by two phase: (1) searching the BMN whose reference vector was closest to elements of the input vector not including the satisfaction indexes and (2) extracting the satisfaction factor in the BMN's reference vector. First, to confirm whether the SOM training was sufficiently finished, the satisfaction index was estimated using the original input data set that was used for the training. Since a correlation factor between the actual satisfaction and the estimated one was as high as 0.99, the SOM training was sufficient. Second, new SOM was trained using a half of the input data set from each group shown in Table III, and the cross-validation was performed using the other half of the input data set. As a result, the correlation between actual satisfaction indexes and the estimated ones were as low as 0.14-0.16, and accuracy of the obtained SOM model was insufficient.

To remake the value-sympathy model, the multivariate regression analysis and the principal components analysis (PCA) to the web questionnaire items were tried. Concerning "guests' attitude of values to a hotel service", PCA found the following three interpreted components from eight items: 'a concern to hotel staff', 'patience', and 'selfish'. (Cumulative contribution ratio of the three components is 55.5%.) Hence, the original eight items were converted into there three variables corresponding to the interpreted components using the obtained weight coefficients. Moreover, the factor analysis with a promax rotation against 17 questionnaire items showed that other items (='Do you want to utilize the hotel again?') could reflect comprehensive satisfaction better than the original items (='How happy are you with the hotel's service comprehensively?'). Hence, this new item was newly used as satisfaction variable J. New SOM was trained using new input data after above-mentioned modification. As a result, similar cross-validation showed that the correlation of satisfaction could be improved as large as 0.28.

V. DISCUSSION FOR FUTURE WORK

Through the case-study concerning the hotel service, requirements for the value-sympathy model, several findings, and a future direction could be found. Below are the discussions of these topics.

Improvement of accuracy of the SOM model
In order to actually utilize the mathematical service model, it is necessary to enhance the generalization capability of the SOM based value-sympathy model. Through a modeling process in this study, the following issues for this aim were confirmed: (a) elimination of abnormal data, (b) adequate selection and integration of the service variables for the model, and (c) adequate normalization of the input vector for the SOM training. Especially the issue (b) is significant, and it was also confirmed in Section IV-D that pre-analysis using statistical approaches with the principal component analysis and the factor analysis was useful for an enhancement of the modeling. An establishment of a rigid procedure to build a model is expected in future.

Realization of the service optimizer
The purpose of the present study is a deliberation of how to build the value-sympathy model, and how to provide adequate service based on the value-sympathy model was not treated yet. The present authors are, however, expecting that the SOM map will enable to determine the best service depending on the circumstance. Specifically, utilizing the trained SOM which holds a relation between client information (x and y), received service (u), and guest's satisfaction (J) as functional database, it is expected that a manipulatable service factor maximizing J can be searched by tracing the smooth elastic SOM map like an artificial potential field. Outline of the algorithm is mentioned below, and the conceptual illustration is shown in Fig. 6.

1) A search input vector $\bar{\mathbf{x}}$ is constructed by summarizing the information that could only be known about recipient's status x and behavior y. Elements in $\bar{\mathbf{x}}$ corresponding to unknown information are specified by zeros.
2) The BMN against $\bar{\mathbf{x}}$, c_0, is searched by considering the zero-elements of $\bar{\mathbf{x}}$:

$$c_0 = arg \min_k \{\|\bar{\mathbf{x}} - p \circ m'_k\|\} \quad k = 1, \cdots, L, \qquad (3)$$

where m' is trained reference vectors, $p \in \{0,1\}^n$ is a mask of which factors have '1' at the corresponding

non-zero elements in $\bar{\mathbf{x}}$, and $\circ$ is an arithmetic operator that extracts elements of m' according to the positions of '1' elements in the mask p.
3) Checking the values of satisfaction obtained from the reference vectors of nodes which are located around the node c_0 on the SOM plane map, an other node maximizing J, c_*, is found by the gradient search.
4) Computing two values of operable inputs from the reference vector of the node c_* and of the node c_0, that are u'_{d*} and u'_{d0}, the difference value $u'_{d*} - u'_{d0} =: u_d$ is determined to be a service input. Lastly, an action corresponding to the u_d is performed by the provider, and the service is provided to the recipient.

Above-mentioned algorithm is just a conceptual idea now, and an establishment of the actual service determination method is a subject for a further study after an establishment of the high-precision modeling.

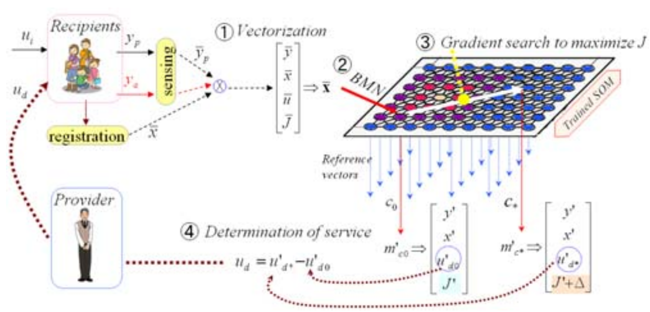

Fig. 6. Outline of service determination algorithm

Practical verification of the value-sympathy model

In formulation of the model, the service input u was considered as the manipulatable factor of which ASA or a human can provide. In this paper, however, the service input was not yet utilized in practice. Hence, to demonstrate an effectiveness of the value-sympathy model, it is necessary to provide the service input by using an actual ASA machine implemented with the model, and to verify the difference experimentally. An evaluation method and an experimental task design are also subjects of future investigation.

VI. Conclusion

A new concept of the artificial system ASA (adaptive service attendant) which adaptively provides service to human was introduced in this paper. And a concept and formulation for the value-sympathy model required for an implementation of service actions in ASA were also proposed. Based on a relation between a service provider and a service recipient, needful factors such as manipulatable input variable and experience factors were shown.

And the following steps to design the value-sympathy model was presented: 1) qualitative analysis to the providers, 2) quantitative analysis from the recipients, 3) pre-processing by the factor analysis, and 4) mathematically modeling using the SOM (Self-Organizing Map) technique. The first step is a clarification of the qualitative structure inside the target service by the qualitative analyses such as the interview analysis, observational investigation, and M-GTA (modified grounded theory approach). The second step is a questionnaire design based on the knowledge obtained in the first step. After quantitative data was obtained with questionnaire, adequate service variables are selected and unified by factor analysis against the quantitative data in the third step. The fourth step is a training process of the SOM to convert the obtained information into a mathematical model.

A case-study to the hotel guest service was shown to actually explain the design procedure involving these steps. A qualitative analysis of the hotel customer service was performed to the several hotel staffs. The result was reflected to items of the web questionnaire, and the data obtained through the questionnaire were utilized to build the value-sympathy model using SOM. The accuracy of the model was evaluated by the cross-validation comparing the actual satisfaction and the estimated one using the model. When the variables for the SOM training were intuitively selected, the matching ratio of the estimation was as low as 0.14-0.16. However, when the selection was modified using preliminary analyses of the principal component analysis and the factor analysis, the matching ratio could be improved to 0.28.

At present the accuracy of the model is not sufficient. Improvement of the model accuracy, establishment of an algorithm to determine adequate service item to maximize the guest satisfaction, and practical verification should be performed to realize ASA. Although various issues still remain, the present authors believe that a direction to utilize the value-sympathy model concerning the service engineering could be shown.

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