

Participatory Service Design Based on User-centered QoS

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Abstract—With the development of service-oriented computing environments, more and more Web services have become available. Service providers have to consider how to design composite services to meet requirements from various users. However, QoS of composite service is difficult to evaluate and predict due to the uncertainty and multiple metrics of QoS, which makes it necessary for user-centered design of composite services. Moreover, combining human services and Web services is becoming an important issue in service composition in cases that Web services cannot meet the requirements from users. Therefore, it is necessary to test the service composition environments for human-computer interaction and study human behaviors. In this paper, we address the above issues by proposing a participatory service design approach based on user-centered QoS considering a real-world case of field-based multi-language communication service design. To achieve this goal, we first describe the QoS model for service design considering users' requirements. Then, we propose the participatory service design process, consisting of service model refinement, participatory simulation, QoS evaluation and QoS data update. Finally, we use the field study of multi-language service design for Vietnamese agricultural knowledge communication to illustrate our proposed design methodology.

Keywords—Quality of service; user-centered QoS; service composition; multi-language communication service; participatory design

I. INTRODUCTION

Service-oriented environments enable people to create, manage their own services, and share their services with each other, while users can get additional value of services by composing them based on their own requirements. For example, the Language Grid [1], a typical example of service composition environments in the domain of language services, can be used for designing multi-language communication services for real application fields by combining various atomic language services including machine translation services, dictionary services, parallel text services and so on. However, it is important to consider users' requirements when designing such composite services. QoS-aware service design has been much studied in the past years, where service composition has been regarded as QoS optimization problem. In such problems, atomic services that generate maximum overall QoS value with constraints are selected as optimized solution [2] [3] [4]. To meet users' requirements, QoS data is extremely important for simulation, evaluation and selection of services. QoS prediction are proposed in some work including the approaches of

usage of history data, user experience and so on [5] [6].

However, there are several important issues that we should deal with in the QoS-aware service composition. First, the performance of services may fluctuate due to dynamic change of service environments [7] and therefore QoS is inherently uncertain [8], which makes it difficult to design composite service based on QoS. Second, when there are multiple QoS metrics for services, it is difficult to maximize all the QoS metrics because there might always be anti-correlated relations between them [9]. For example, improvement of translation quality in multi-language communication service might always bring the increasing of translation cost. Therefore, it is necessary to design composite service based on users' requirements, i.e., service composition should be designed based on user-centered QoS. Moreover, combining human services and Web services is becoming an important issue in service composition [10] [11] [12] in cases that pure Web services cannot meet the requirements from users. Therefore, it becomes important to test the service composition environments for human-computer interaction and study human behaviors for QoS evaluation.

To address above issues, we are aiming at proposing a participatory service design approach based on user-centered QoS, which users' satisfaction are evaluated during the whole service design process. To achieve this goal, we first describe a QoS model for service design considering users' requirement by extending previous models. Then, we propose the participatory service design process, consisting of service model refinement, participatory simulation, QoS evaluation and QoS data update. Finally, we use a field study of multi-language communication service design to illustrate our propose design methodology.

The rest of the paper is organized as follows: Section II introduces some related work for understanding the background and features of our research. In Section III, we provide a motivating example on multi-language communication service design in a real application field to show our research problem, and then describe a QoS model of multiple metrics for user-centered QoS evaluation. Section IV describes the participatory service design approach considering users' requirements. Section V introduces a case study based on field experiments to show how our proposed approach is effective to design composite services. Finally, the conclusion is presented in the last section.

II. RELATED WORK

In this section, we introduce some related work on QoS-aware service composition and human services, and then show the features of our research.

QoS-aware service composition and selection has been widely studied in the area of service-oriented computing. Zeng *et al.* proposed a multidimensional QoS model for Web service composition with several optimization approaches for service selection in both static environment and dynamic environment based on QoS aggregation [2]. To deal with multiple QoS attributes, QoS-based service selection processes considering normalization and weighted aggregation were proposed in some work [15] [16]. Huang *et al.* described the QoS aggregation for different workflow patterns in a composition service [18]. User factors has also been considered in service selection. For example, the process of filtering Web service according to user preference was described by Cao *et al.* [17]. To deal with dynamic service selection problem, QoS prediction has been studied including approaches of usage of history data, user experience and so on [5] [6]. However, most of above work neglected the difficulties of QoS issues in the real service composition environments. First, there are situations that some QoS metrics cannot be aggregated for composite services. For example, it is difficult to compute the translation quality of a composite translation service by simply aggregating its component atomic service (machine translation service, morphological analysis service, dictionary service, etc.). Second, when there are multiple QoS metrics for services, it is always difficult to maximize all the QoS metrics because there might always be anti-correlated relations between them. Alrifai *et al.* proposed several types of relations of different QoS metrics: independent, correlated, and anti-correlated [9], which is also useful in our research. Third, QoS values always vary based on different context for different types of service invocation, which has been pointed out as QoS uncertainty [8]. Therefore, it is important to evaluate uncertain QoS and consider users' requirements when designing composite services. In our research, we focus on user-centered QoS for designing composite services. In user-centered service design, it is necessary to evaluate users' satisfaction (or user-centered QoS), which is the focus of our research.

Complicated services in real application fields cannot always be realized by composing pure Web services. To deal with this issue, combining human service and Web service has become an important issue in recent years with the development of crowdsourcing and cloud computing environments. Truong *et al.* proposes a method for modeling clouds of human services and combine human services with software-based Web services to establish clouds of hybrid services. Kern *et al.* proposes a statistical quality control approach for human services and testifies their approach using crowdsourcing experiments [10]. Efforts of dealing with human services in crowdsourcing environments can be also found in some other work [11] [12]. To design multi-language communication (or translation) services, attempts of combining human services

and Web services have been reported in previous research [19] for ensuring the translation quality. However, most of the previous researches focus on the quality control of human services and the composition mechanisms of hybrid services. It is extremely important to test the service composition environments for human-computer interaction and study human behaviors. Therefore, in this paper we use participatory service design approach to deal with the QoS uncertainty issues and human-computer interaction issues.

III. QoS MODEL FOR SERVICE DESIGN

A. Motivating Example

We use the design of multi-language communication services as a motivating example of this research. With the increasing of various language resources (machine translators, multi-language dictionaries, parallel texts, etc.) available on the Internet, it becomes possible for people to design their own multi-language communication services by composing various language resources/services based on their requirements [1] [20]. The Language Grid¹ is developed to provide a service composition environment for users to share, create and combine language services [1]. By August 2013, 145 organizations from 18 countries and regions have become users of the Language Grid, and over 170 atomic language services and composite services of 25 service types (machine translation service, dictionary service, parallel text service, morphological analysis service, and so on) are provided on the Language Grid². Besides, humans are also possible to be wrapped as Web services on the Language Grid [12]. In the Language Grid, multiple QoS metrics are managed for language services, including both general metrics like response execution time and cost, and domain specific metrics like translation quality [20]. However, difficulties arise due to the uncertain QoS of different language services. Therefore, it is necessary to provide a general approach for designing the multi-language communication services.

Figure 1 shows the available atomic language services for designing a multi-language communication service between Vietnamese and Japanese for a field-based project in Vietnam to support Vietnamese farmers to deal with rice cultivation problems by Japanese agriculture experts. Multi-language communication service should be designed for implementing tools. Then, how to design an appropriate composite service to satisfy users' requirements? Moreover, it seems that we have to combine human services for the communication service design. How to test the service composition environments for interaction between human service and software and data based Web services? In this paper, we try to address above issues by proposing a participatory service design approach based on user-centered QoS.

¹<http://langrid.org/>

²Lists of Language Grid users and services are available in the Language Grid Service Manager (http://langrid.org/service_manager/)

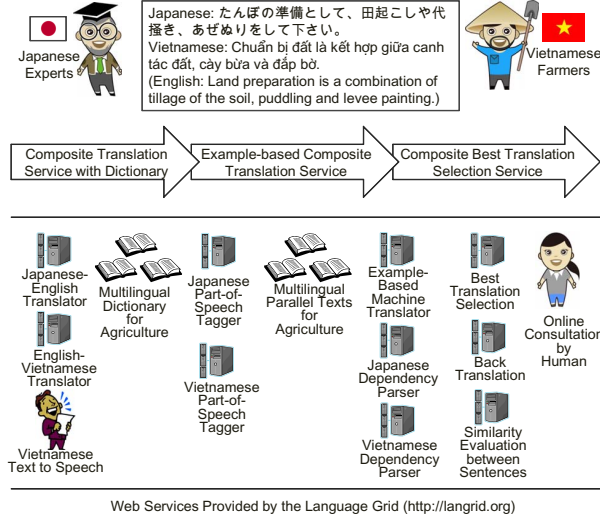


Fig. 1. Web services for composition.

B. User-Centered QoS

QoS model has been much discussed in previous work. Zeng *et al.* [2] proposed a multidimensional QoS model for service composition, which has later been the basis of the research in this area. Some work also considered the domain specific QoS metrics. For example, Canfora *et al.* emphasized the important of combination of application specific QoS [21]. Ma *et al.* described the semantic view of QoS based selection, with emphasis on domain specific property [22]. In this research, we consider both generic QoS metrics like cost, and domain-specific QoS metrics like translation quality for machine translation services.

To build the QoS model for service design, we use the definition for QoS metric as what has been defined in most of the previous work, i.e., the i^{th} QoS metric of service s is represented as $q_i(s)$. We use $Q_s = (q_1(s), q_2(s), \dots, q_n(s))$ to represent the vector of QoS values of service s . Composite service can be created and refined based on QoS evaluation to satisfy users' requirements. To meet users' requirements, QoS data is extremely important for simulation, evaluation and selection of services. Considering the uncertainty of values of QoS metrics in multi-language communication services, we use quality range to describe the property of the QoS metrics. Mohabbatiet *al.* proposed an approach for aggregating the quality range of composite services from that of atomic services [23], which can also be used in this research, i.e., the quality range of the i^{th} QoS metric of service s can be defined as $q_i^R(s) = [q_i^{LB}(s), q_i^{UB}(s)]$, where $q_i^{LB}(s)$ and $q_i^{UB}(s)$ are lower and upper bound values of the QoS metric respectively.

Since different QoS metrics have different computation methods, it is necessary to normalize different QoS metrics when quality range is considered for aggregating multiple QoS metrics for service selection. The normalization of QoS metric uses the min-max Equation (1)

$$q'_k(s) = \begin{cases} \frac{q_k(s) - \min(q_k(s))}{\max(q_k(s)) - \min(q_k(s))} & \text{if QoS metric is positive} \\ \frac{\max(q_k(s)) - q_k(s)}{\max(q_k(s)) - \min(q_k(s))} & \text{if QoS metric is negative} \end{cases} \quad (1)$$

where $\max(q_k(s))$ and $\min(q_k(s))$ are the maximum value and minimum value of QoS metric $q_k(s)$ that can be expected for all the services.

If a QoS metric is the type of gaining, it is called positive, e.g., the adequacy of translation results. Otherwise, the attribute is type of the paying, and it is called negative, e.g., the cost that should be paid for invoking services. The quality range of the i^{th} QoS metric of service s after normalization can be described as $q_i^R(s) = [q_i^{LB}(s), q_i^{UB}(s)]$ respectively. This normalization approach may not be applicable to some QoS metrics with high variation with a skewed distribution; for example, even for a Poisson distribution, it could have a large max value but the mean may be relatively small. Some previous work focuses on how to solve the normalization methods of QoS metrics [24], which is not the focus of this paper but is possible to be extended to apply in our research.

We define QoS requirements from a user as $C(s) = (c_1(s), c_2(s), \dots, c_m(s))$, where $c_l(s)$ is the l^{th} QoS constraint from the user over service s . We use $P(s) = (p_1(s), p_2(s), \dots, p_m(s))$ to define whether the QoS constraint is satisfied or not. For each QoS constraint $c_l(s)$, $p_l(s)$ is calculated as Equation (2).

$$p_l(s) = \begin{cases} 1 & \text{if } c_l(s) \text{ is satisfied} \\ 0 & \text{if } c_l(s) \text{ is not satisfied} \end{cases} \quad (2)$$

We use $w_k \in [0, 1]$ to define the weight of c_k that is decided by user priority of QoS constraints, where $\sum_{k=1}^m w_k = 1$.

To evaluate the user satisfaction, we use two types of utility functions: utility of feasibility $Utility_F(s)$, and utility of optimity $Utility_O(s)$, which has been proposed in our previous work [25].

Utility of feasibility is used to evaluate whether the service selection is feasible based on user requirements, and is calculated by Equation (3). $Utility_F(s) = 1$ means that all the QoS constraints from the user are satisfied. Otherwise, there is one or more constraints are not satisfied.

$$Utility_F(s) = \prod_{k=1}^m p_k(s) \cdot w_k \quad (3)$$

Utility of optimity is used to evaluate whether the service selection is optimal based on user requirements, and is calculated by Equation (4). $Utility_O(s)$ is meaningful only when $Utility_F(s) = 1$. $w'_k \in [0, 1]$ is the weight of $q_k(s)$ that is decided by user priority of QoS metrics, where $\sum_{k=1}^n w'_k = 1$.

$$Utility_O(s) = \sum_{k=1}^n q'_k(s) \cdot w'_k \quad (4)$$

In previous work, Alrifai *et al.* proposed several types of relations of different QoS metrics: independent, correlated,

and anti-correlated [9], which is also useful in our research. In the independent type, the values of two QoS metrics are independent to each other, e.g., the QoS metrics of response time and translation quality in a translation service. In the correlated type, a service that is good in one attribute is also good in the other attribute. In the anti-correlated type, there is a clear trade-off between the two attributes, e.g., the QoS metrics of translation quality and cost in a translation service. In the case of anti-correlated type, *Utility of optimity* is affected by the weights based on users' requirements.

IV. PARTICIPATORY SERVICE DESIGN

The requirement of human-computer interaction has been increasing in software development and also service-oriented computing. It has become essential to use the user-centered approach when creating interactive systems [13]. In user-centered service design, it is natural to evaluate users' satisfaction during the design process. Moreover, when designing hybrid composite service composed by Web services and human services considering the uncertainty of QoS, it is necessary to simulate the human services. Therefore, we need a new approach for service design. In this paper, we propose the participatory service design approach for satisfying users' requirements. Participatory design has been proposed in community informatics [14] and multiagent systems [13], which is new in service-oriented computing especially in the context of user-centered QoS for service composition.

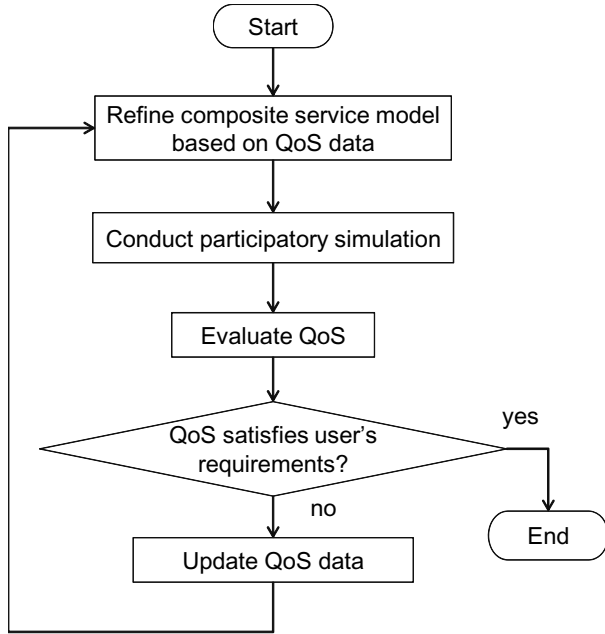


Fig. 2. Participatory service design process.

Figure 2 shows the process of participatory service design for satisfying users' QoS requirements. The proposed approach can be mainly explained as the following steps.

(1) *Refine composite service model based on QoS data*: Composite service for participatory simulation is created/refined by service selection based on the QoS data. **Algorithm 1** shows how the refinement process is conducted. Predicted utility of feasibility $Utility_F^p(s_i)$ of each candidate available composite service is calculated based on the quality upper bound values of the QoS metrics and user requirements. If the candidate is feasible ($Utility_F^p(s_i) = 1$), predicted utility of optimity $Utility_O^p(s_i)$ will be further calculated. The candidate service with the largest utility of optimity will be selected as the candidate service model for participatory simulation.

Algorithm 1 Service Model Refinement

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procedure ServiceModelRefinement ( $s^*, S_{UF}, C$ )
1:  $s^*$  (composite service model for simulation)
2:  $S \leftarrow$  set of all available composite services
3: /*  $S_{UF}$ : set of all composite services that have failed to
   satisfy users' requirement  $C$  during participatory simulation */
4:  $S_{UF} \leftarrow \{s^*\}$ 
5:  $MaxUtilityO \leftarrow 0$ 
6: for all Composite service  $s_i \in S - S_{UF}$  do
7:   for all QoS metric  $q_j(s_i) \in Q_{s_i}$  do
8:     Compute  $q_j^R(s_i) = [q_j^{LB}(s_i), q_j^{UB}(s_i)]$ 
9:      $q_j'(s_i) \leftarrow q_j^{UB}(s_i)$ 
10:  end for
11:  Compute predicted Utility of feasibility  $Utility_F^p(s_i)$ 
   based on Equation (3)
12:  if  $Utility_F^p(s_i) = 1$  then
13:    Compute predicted Utility of optimity  $Utility_O^p(s_i)$ 
   based on Equation (4)
14:     $s^* \leftarrow \arg \max_{s_i} Utility_O^p(s_i)$ 
15:  end if
16: end for
17: return  $s^*, S_{UF}$ 
  
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(2) *Conduct participatory simulation*: After obtaining the composite service in the model refinement step, participatory simulation will be conducted. In the selected composited service, human activities will be simulated by human participants, whose features are selected or trained to be similar to the human services in the composite service. Participatory simulations are useful for controlled experiments because they make it easy to prepare the environment for testing [13]. To conduct the participatory simulation, the service designer does not have to create a real service-based system. Instead, all the interactions between computer (services) and human is described using simple scenario description languages like the *Q* Language [26]. Figure 3 shows an example of simulating Japanese-Vietnamese composited translation service in the application field we have described in Section III. We have developed a participatory simulation tool for service design by extending the *Q* Language, on which the simulation scenario in Figure 3 can be conducted. To summarize, participatory

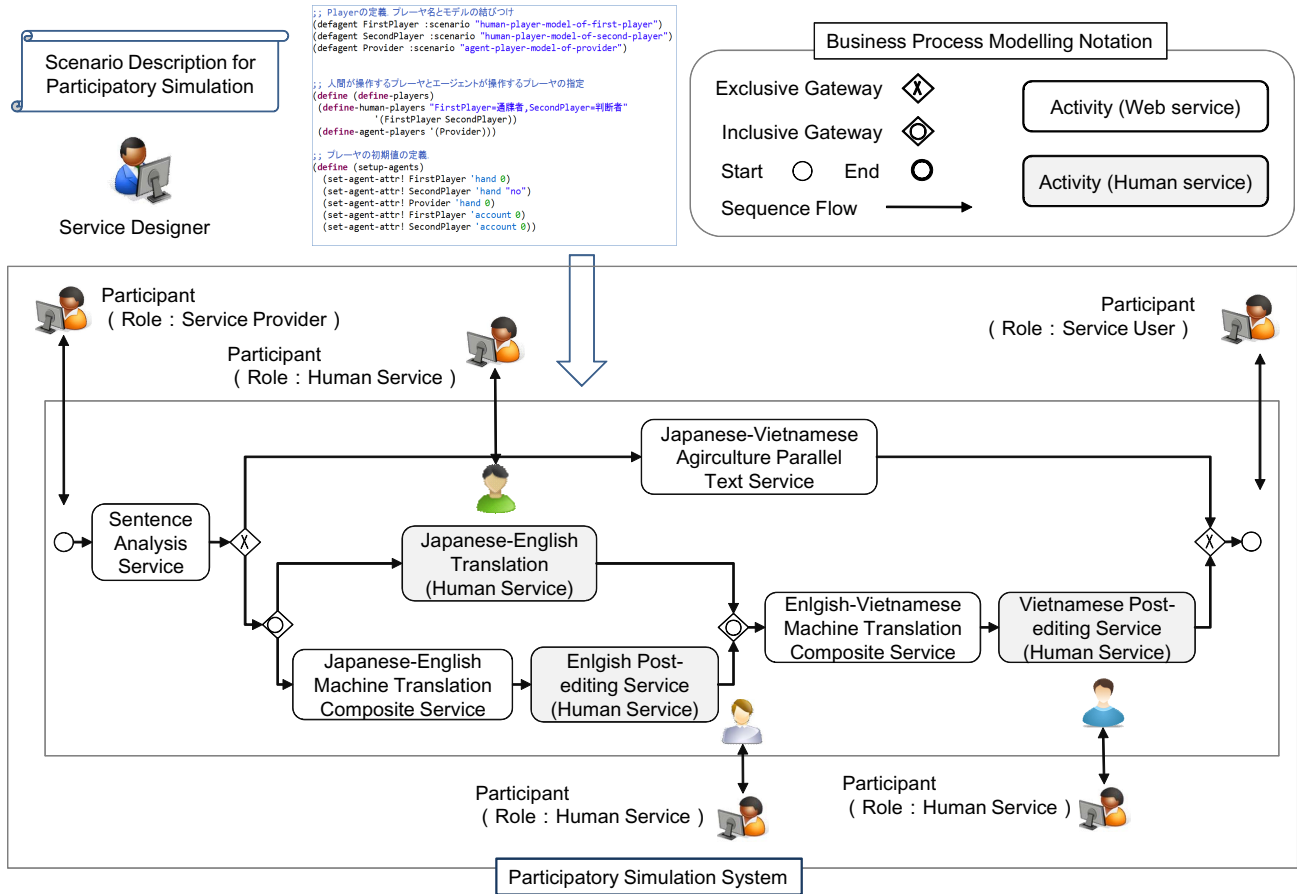


Fig. 3. Designing composite multi-language communication (Japanese-Vietnamese translation) service using participatory simulation.

simulation consists of four sub-steps: simulation scenario description, participant assignment, simulation execution, data analysis.

(3) *Evaluate QoS*: In participatory simulation, the log data of the participants can be used for analysis and refinement of the service model. Therefore, the real values of QoS metrics will be obtained from the execution of the simulation, which will be used for interactive service model refinement. In this step, if the evaluated QoS can satisfy users' requirements in the participatory simulation, real-world experiments (field application) can be further conducted. Otherwise, composite service should be refined.

(4) *Update QoS data*: QoS data will be updated based on the result of participatory simulation for further user-centered service modeling and refinement. The participatory design is an iterative process until the simulation result satisfies user requirements.

In next section, we will use a case of multi-language communication service design to illustrate the above process. Although the proposed service design approach is testified with the multi-language communication design case, it can be extended to a more general methodology considering various

QoS models in service composition environments.

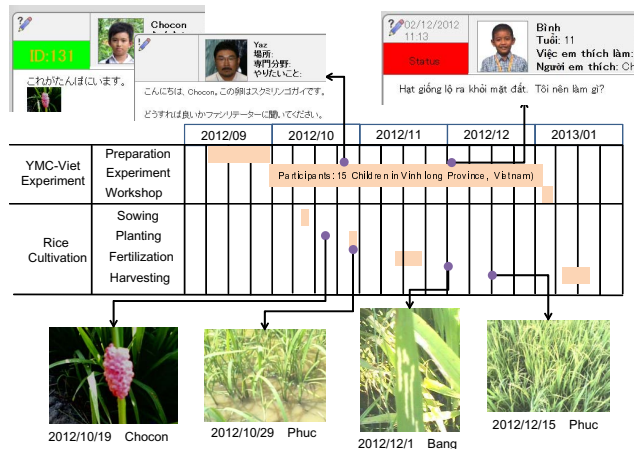
V. CASE STUDY: MULTI-LANGUAGE COMMUNICATION SERVICE DESIGN

To testify and analyze how our proposed approach is effective for service design, especially in the hybrid service composition environments with software and data based Web services and human services, we conduct a field experiment (YMC-Viet project³) to design multi-language communication service for supporting Vietnamese farmers as we have mentioned in Section III. This project has been conducted for two seasons (February 2011, and October 2012) in Thien My Commune, Tra On District, Vinh Long Province, Vietnam with 30 and 15 participants respectively.

The YMC-Viet project was conducted in cooperation with Ministry of Agriculture and Rural Development of Vietnam (MARD) as part of a model project to support developing countries with ICT. Since the literacy rate of farmers in this area is low, youths (children) with high literacy acted as mediators between Japanese experts and Vietnamese farmers.

³http://www.agroviet.gov.vn/en/Pages/news_detail.aspx?NewsId=923

Figure 4 shows some examples of the multi-language communication between Vietnamese youths and Japanese Experts through the service-based multi-language communication tool (YMC system) during the rice cultivation. Youths sent local data (regarded as sensor service) and questions via the YMC system as shows in the bottom part of Figure 4. Japanese Experts got local data and questions from the youths via the YMC system and answer the questions in Japanese, which will be translated into Vietnamese and feed backed to the Youths.



(a) Usage of YMC system during the rice cultivation period.



(b) Interface of YMC system for Youths and Experts.

Fig. 4. YMC system based on multi-language communication service design in the second season of YMC-Viet field experiment in Vinh Long Province, Vietnam (during October 2012 to January 2013).

To realize the multi-language communication service for the communication tool for YMC-Viet project, there are many available composite services, e.g., human translation, parallel text service, machine translation service combined by dictionary⁴, and so on. All these composite services can be created based on the atomic services in Figure 1. Table I shows a part of the Web services provided by the Language Grid

⁴http://langrid.org/service_manager/wsl/st/nict.nlp:TranslationWithTemporalDictionary

TABLE I
LIST OF WEB SERVICES AND HUMAN SERVICES FOR MULTI-LANGUAGE COMMUNICATION SERVICE DESIGN IN THE YMC-VIET EXPERIMENT.

Service	Description
s_1	Composite Japanese-Vietnamese machine translation service combined with agriculture dictionary (Composite Web Service)
s_2	Composite Japanese-English machine translation service combined with agriculture dictionary (Composite Web Service)
s_3	Composite English-Vietnamese machine translation service combined with agriculture dictionary (Composite Web Service)
h_1	Japanese pre-editing service (Human Service)
h_2	English post-editing service (Human Service)
h_3	Vietnamese post-editing service (Human Service)
h_4	Japanese-English human translation service (Human Service)
h_5	Japanese-Vietnamese human translation service (Human Service)

and human services for the experiment. QoS in the language service domain consists of non-functional QoS metrics (cost, execution time, etc.) and functional QoS metrics (translation quality). In our experiment, cost, execution time and translation quality are used as QoS metrics. The QoS metric cost is correlated with execution time, while anti-correlated with translation quality. The users' requirement for two QoS metrics is $q_{translation_quality}(s) > 0.7$ (weight is 0.2) and $q_{cost}(s) > 0.5$ (weight is 0.8) respectively after normalization.

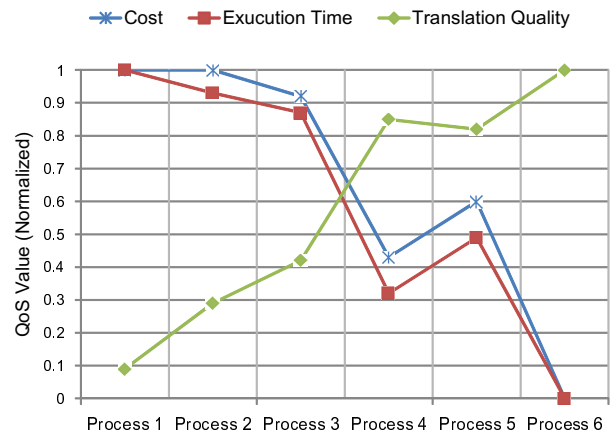


Fig. 5. Relations between different QoS metrics during participatory service design: correlation (cost and execution time), anti-correlation (translation quality and cost, translation quality and execution time).

We use the participatory service design approach proposed in this paper for designing the multi-language communication service before the first season experiment in 2011. Table II shows the participatory design result (from Process 1 to Process 5) based on the design process proposed in Figure 2. Moreover, the relationship between the three QoS metrics of the five processes is shown in Figure 5, which explains

TABLE II
COMPOSITE SERVICES FOR PARTICIPATORY SIMULATION USED IN THE YMC-VIET EXPERIMENTS AND EVALUATION RESULT OF THE QoS VALUES.

Composite Service	Composed Services and Flow	QoS Value		
		Cost (USD)	Execution Time (min)	Translation Quality
Process 1	s_1	0.10	0.01	1.36/5.00
Process 2	$h_1 \rightarrow s_1$	1.33	10	2.14/5.00
Process 3	$h_1 \rightarrow s_1 \rightarrow h_3$	3.33	20	2.67/5.00
Process 4	$h_4 \rightarrow s_3 \rightarrow h_3$	25.18	102	4.40/5.00
Process 5	$h_1 \rightarrow s_2 \rightarrow h_2 \rightarrow s_3 \rightarrow h_3$	17.51	77	4.28/5.00
Process 6	h_5 (for comparison)	44.00	150	5.00/5.00

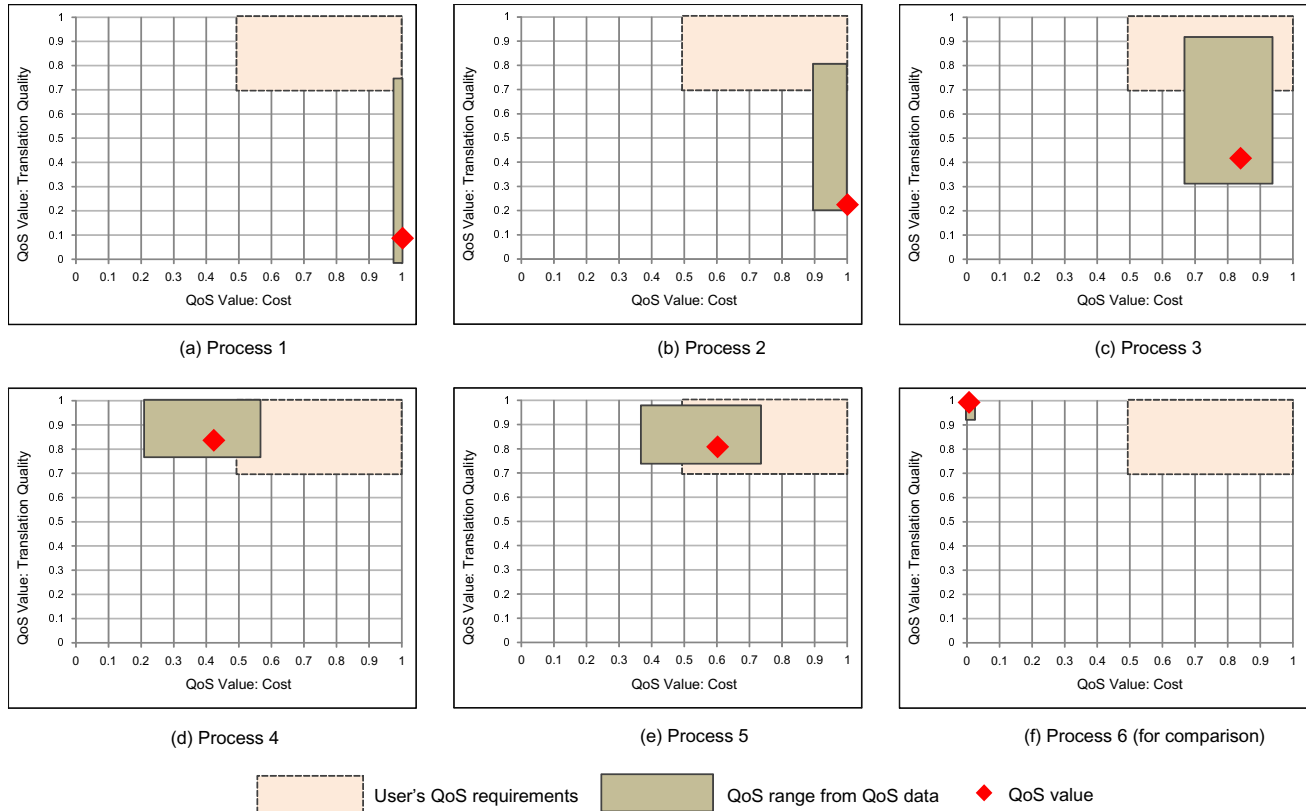


Fig. 6. Change of composite services (from Process 1 to Process 5) and QoS values with participatory service design.

the anti-correlation between cost and translation quality, and correlation between cost and execution time. As a result, the composite service Process 5 satisfied users' requirements and is optimal among all the composite services, which was used as the service model to implement the multi-language communication tool for the field experiment in season 2011. Figure 6 shows the details of the quality range and QoS value in each process.

The final service model (Process 5) worked well for the field experiment. However, there are several issues that should be considered in the future. First, it is not effective to use quality range for refinement of service model because quality range is large and cannot always reflect the prediction. That

is why it took us four times' refinement before reaching the composite service model. One way to deal with this issue is to consider the recent quality range but not only the quality range over all the time. Second, although composite service selected for participatory simulation is supposed to satisfy the users' requirements, the result sometimes turns out to be negative. There are two possible reasons: one is the uncertainty of the QoS data, and the other is the failure of providing reality by human participants in the simulation. Therefore, it is also necessary to conduct real-world experiments as well as virtual participatory simulation. Finally, the service design problem would become more complicated if there are more QoS metrics when they anti-correlated with each other,

which makes it difficult to satisfy users' requirement. In that case, negotiation between service users and service providers might be necessary. Therefore, service improvement should be dynamically conducted not only in the service design phase but also in the service execution phase, which is our future direction.

VI. CONCLUSION

There are two important issues in service design for real field-based applications in the service composition environments. One issue is how to design composite services to meet requirements from various users considering the uncertainty of QoS evaluation. The other is how to test the hybrid service composition environments with human services and Web services when pure Web services cannot meet the requirements. To address these two issues, this paper proposed a participatory service design approach based on user-centered QoS considering a real-world case of designing multi-language communication service.

We first extended the QoS model proposed in previous work considering users' requirement by defining two types utilities (utility of feasibility and utility of optimality) to calculate user-centered QoS. Then, we proposed the participatory service design process, consisting of service model refinement, participatory simulation, QoS evaluation and QoS data update. Finally, we used the field study of multi-language communication service design for Japanese-Vietnamese agricultural knowledge communication to illustrate the effectiveness of our proposed design methodology.

Although the proposed service design approach is testified with the multi-language communication design case, it can be extended to a more general methodology considering various QoS models in service composition environments. Our future work will focus on user-centered QoS evaluation, prediction for service design, and dynamic service refinement in execution.

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