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QoS Analysis for Service Composition by Human and Web Services

Donghui LIN^{†a)}, Member, Toru ISHIDA[†], Fellow, Yohei MURAKAMI[†], and Masahiro TANAKA^{††}, Members

SUMMARY The availability of more and more Web services provides great varieties for users to design service processes. However, there are situations that services or service processes cannot meet users' requirements in functional QoS dimensions (e.g., translation quality in a machine translation service). In those cases, composing Web services and human tasks is expected to be a possible alternative solution. However, analysis of such practical efforts were rarely reported in previous researches, most of which focus on the technology of embedding human tasks in software environments. Therefore, this study aims at analyzing the effects of composing Web services and human activities using a case study in the domain of language service with large scale experiments. From the experiments and analysis, we find out that (1) service implementation variety can be greatly increased by composing Web services and human activities for satisfying users' QoS requirements; (2) functional QoS of a Web service can be significantly improved by inducing human activities with limited cost and execution time provided certain quality of human activities; and (3) multiple QoS attributes of a composite service are affected in different ways with different quality of human activities.

key words: quality of service, service composition, human service

1. Introduction

Quality of service (QoS) has been regarded as an important factor when selecting and composing Web services. In QoSaware service composition, general QoS dimensions are always defined, including cost, execution time, response, reputation, availability and so on [1], which are very important to evaluate non-functional quality of atomic services and composite services. Besides, many approaches of computing QoS from multiple dimensions have been reported [1]– [3]. However, application-specific QoS (functional QoS) dimensions might also be essential. In the case of translation services, users care about the translation quality rather than general dimensions in most circumstances. Therefore, it is important to keep the translation quality while considering other QoS dimensions.

With the global expansion of service-oriented computing, more and more Web services are provided for users by all kinds of providers. As a result, many tasks in traditional workflow process can be conducted either by human activities or Web services. However, there are several important issues we should deal with in the QoS-aware service composition. First, the performance of services may fluctuate due

[†]The authors are with the Department of Social Informatics, Kyoto University, Kyoto-shi, 606–8501 Japan.

^{††}The author is with National Institute of Information and Communications Technology, Kyoto-fu, 619–0289 Japan.

a) E-mail: lindh@i.kyoto-u.ac.jp

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to dynamic change of service environments [4] and therefore QoS is inherently uncertain [5], which makes it difficult to design composite service based on QoS. Second, when there are multiple QoS attributes for services, it is always difficult to maximize all the QoS attributes because there might always be anti-correlated relations between them [6]. Moreover, some important functional QoS dimensions cannot always meet users' requirements due to application-specific limitations or other limitations, e.g., it is always impossible for machine translation service to provide perfect translation results for users.

To address this issue, combining Web services and human activities is expected to be a solution. Although human activities has been studied in the area of workflow management and business process management, they are always considered from the perspective of organization view or resource view [7], [8] to be conducted when tasks cannot be processed by software or services. In recent years, with the development of crowdsourcing and cloud computing environments, combining human services and Web services is attracting attentions and becoming an important issue in service composition [9]–[11]. In service oriented platforms, it becomes necessary to compose crowd activities with services to bring creativity to the traditional service-based business processes. In this paper, we aim at practicing and analyzing the effect of composition of human activities and Web services in the real world. The human activities in this research involve both crowd workers and professionals. Specifically, we consider the human activities in a perspective of QoS which was always neglected in previous research. A good example in language service domain is that translation work can be done by composing machine translation services, monolingual crowd workers and bilingual professionals.

The rest of the paper is organized as follows: Section 2 provides a motivation example in the language service domain. In Sect. 3, basic types of composing Web services and human activities are defined for QoS improvement. Section 4 and Sect. 5 introduces a case study in the language service domain with experiments and analysis. Section 6 introduces some related work. In Sect. 7, we will conclude the work.

2. Language Service Composition Example

To explain the problem, we show a motivation example in the language domain. We use the example of language trans-

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lation which can be achieved in two ways: human translation and machine translation. To provide flexible language services, we have developed the Language Grid, which is a service-oriented intelligence platform [12], [13]. The Language Grid has been collecting language resources from the Internet, universities, research labs and companies. All the language resources are wrapped as atomic Web services by standard interface. Using the atomic Web services, we have also developed a series of composite services^{*}. Besides, humans activities are also possible to be wrapped as Web services on the Language Grid [11]. In the Language Grid, multiple QoS attributes are managed for language services, including both general attribute like response execution time and cost, and domain specific attribute like translation quality [14]. In the language service domain, the applicationspecific QoS dimensions (translation quality) are always more essential than other general QoS dimensions. Translations were evaluated on the basis of adequacy and fluency in previous reports [15]. Adequacy refers to the degree to which the translation communicates information present in the original. Fluency refers to the degree to which the translation is well-formed according to the grammar of the target language.

In the Language Grid, language services are categorized in several classes. For each service class, multiple services/composite processes are provided for different QoS requirements. For example, the translation service class includes atomic machine translation service, two-hop machine translation service, machine translation service combined with bilingual dictionary, and so on. By creating a composite machine translation service which combines services including morphological analysis service, dictionary service, machine translation service, the functional QoS can be improved comparing with the atomic machine translation service. However, although many types of services/processes are provided, there still exist limitations in functional QoS dimensions, e.g., machine translation services can never have perfect fluency and adequacy even when they are combined with dictionaries or other services for QoS improvement. That means service-based processes are not able to meet users' requirements in some cases. For example, a composite translation service might be able to deal with the QoS requirement for online chatting, while it is difficult to use a pure service-based process to write business documents or translate the product operation manuals. Figure 1 shows our real problem while we were conducting a project in Vietnam to support Vietnamese farmers to deal with rice cultivation problems by Japanese agriculture experts. To design an appropriate composite service to satisfy users' requirements for language translation in agriculture domain, it seems that we have to combine human activities for the service design. To consider both functional QoS and nonfunctional QoS of translation service, we had a preminalary try to combine human activities and Web services [16] with a small scale experiment. In this paper, we will use large



Fig. 1 Web services for composition.

scale real world example to practice and analyze the effect of composing human activities and Web services.

3. Composition of Web Services and Human Tasks

Considering that there is an existing service process, human activities are possible to be introduced by substituting an atomic service (or a subprocess), forming a selective control relationship with a service (or a subprocess), or processing the input or output of an atomic service (or a subprocess) completely or partially. There are following basic types for introducing a human activity into a service process for improving certain QoS dimensions $Q^S(s)$.

(1) Complete substitution: a human activity ht_i is used to substitute a service s_i (or a subprocess) completely, i.e., $(Q^S(ht_i) > Q^S(s_i)) \rightarrow S(s_i, ht_i)$ (S(a, b) denotes the substitution of a by b for any a and b).

(2) *Partial substitution*: a human activity ht_i is used to form a selective control relationship with a service s_i (or a subprocess) under condition *C*, i.e., $(Q^S((s_i, ht_i, C)) > Q^S(s_i)) \rightarrow S(s_i, (s_i, ht_i, C))$.

(3) *Pre processing*: a human activity ht_i is used to process the input of a service s_i or (or a subprocess), i.e., $(Q^S((ht_i; s_i)) > Q^S(s_i)) \rightarrow S(s_i, (ht_i; s_i)).$

(4) Partial pre processing: a human activity ht_i is used to process the input of a service s_i or (or a subprocess) under condition C, i.e., $(Q^S((ht_i; s_i, C)) > Q^S(s_i)) \rightarrow S(s_i, (ht_i; s_i, C))$.

(5) Post processing: a human activity ht_i is used to process the output of a service s_i (or a subprocess), i.e., $(Q^S((s_i; ht_i)) > Q^S(s_i)) \rightarrow S(s_i, (s_i; ht_i)).$

(6) Partial post processing: a human activity ht_i is used to process the output of a service s_i (or a subprocess) under condition *C*, i.e., $(Q^S((s_i; ht_i, C)) > Q^S(s_i)) \rightarrow S(s_i, (s_i; ht_i, C))$.

For the example of machine translation service process

p, the functional QoS dimensions are fluency and adequacy that consist $Q^{S}(p)$. If the user's requirement of $Q^{S}(p)$ is Q_u and $Q_u > Q^{S}(p)$, then the service process itself cannot meet the user's requirement. In that case, we can introduce human activities to improve $Q^{S}(p)$ to meet the condition $Q^{S}(p) \geq Q_{\mu}$ using one or more approaches from the following possible alternatives: (1) Substitute or partially substitute the machine translation service process p with a human activity for translation ht (Pattern 1 or Pattern 2); (2) Introduce a human activity of modification ht for pre-editing the input translation source sentence (e.g., change long sentences into short forms or change the sequences of words to be handled by translation service more easily) into machine translation service process p (Pattern 3 or Pattern 4); (3) Introduce a human activity of modification ht for post-editing the output translation result (e.g., improve the fluency of the result by a monolingual user) into machine translation service process p (Pattern 5 or Pattern 6). There are also other approaches to compose human and translation services, e.g., using both human activities of pre-editing and post-editing.

The basic patterns can also be extended to more complicated patterns by combing several patterns among them or operating the above patterns on existing human services. QoS aggregation is important for calculating overall QoS of composite services based on QoS data of each atomic service. In previous research, aggregation of QoS functions for composite service has been proposed [1] for non-functional QoS dimensions (e.g, cost and execution time), which is also used in this research. However, functional QoS (e.g, translation quality) of a composite service is always difficult to be aggregated based on the QoS data of each atomic service, which is always obtained after the execution of the composite service or estimated based on historical QoS data of the composite service.

4. Experiment Design for QoS Analysis

To observe and analyze how composition of Web services and human services affects QoS, we conduct a large scale experiment for language translation. The translation processes composed by human services and Web services are based on the patterns (Pattern 5 and Pattern 6) described in Sect. 3. QoS in the language service domain consists of non-functional QoS dimensions (cost, execution time, etc.) and functional QoS dimensions (translation quality, i.e., adequacy of translation result). To observe and analyze the effective of composing human activities and Web services, we design an experiment using three steps to execute the translation process as shown in Table 1.

Main Web services are provided in the Language Grid, including machine translation services, morphological analysis services and dictionary services.

(1) Machine translation services: Web services by wrapping language resources of JServer machine translation service (Japanese (ja) \leftrightarrow English (en), Japanese (ja) \leftrightarrow Korean (ko), Japanese (ja) \leftrightarrow Simplified Chinese (zh-CN) and Japanese (ja) \leftrightarrow Traditional Chinese (zh-TW)) provided

 Table 1
 Translation services/processes used in the experiments.

Steps	Description			
1. CMT	Conduct composite machine translation service which is combined with machine translation ser- vice, morphological analysis service, and dictio- nary service.			
2. CMT+Mono	Introduce human activities of partial post pro- cessing into CMT. The human activities are con- ducted by monolingual users for post-editing a part of results generated by CMT, with the con- dition that monolingual users can understand the machine translation results.			
3. CMT+Mono+Bi	Introduce human activities of partial post pro- cessing into CMT+Mono. The human activi- ties are conducted by bilingual users for confirm- ing the correctness of the post-editing results in <i>CMT+Mono</i> as well as translating the unmodified parts in <i>CMT+Mono</i> . The whole flow is shown in Fig. 2.			



Fig. 2 Translation process composing by Web services and human activities (Step 3: CMT+Mono+Bi).

by Kodensha Co., Ltd, GoogleTranslate translation service (English (en) \leftrightarrow Traditional Chinese (zh-TW)) provided by Google, WebTranser machine translation service (English (en) \leftrightarrow German (de), English (en) \leftrightarrow French (fr), English (en) \leftrightarrow Spanish (es), and English (en) \leftrightarrow Portuguese (pt)) provided by Cross Language Inc.

(2) Morphological analysis services: Web services by wrapping language resources of Mecab Japanese morphological analysis service provided by NTT Communication Science Laboratories, TreeTagger English morphological analysis service provided by University of Stuttgart.

(3) Dictionary services: dictionary service for Business, University and Temple provided by Kyoto Information Card System Limited Liability Company, Ritsumeikan University and Kodaiji Temples.

Two types of human activities are included in the experiment, conducted by monolingual users for post-editing machine translation results and bilingual users for translation and post-editing results generated by the monolingual users. To study how human activities affect QoS of service processes, we use two different settings for the two types of human activities as follows.

(1) Crowd workers for monolingual human activities: low requirements for doing the post-editing tasks. We accept any of the several hundred of registered foreign student users within Kyoto University, Japan. The only requirement is that the registered user is a native speaker of the required modification language. Therefore, the quality of monolingual crowd activity is unanticipatable during the experiment.

(2) Professionals for bilingual human activities:

Process	Instance Number	Services for Composition					
		MT: Web service	Dic: Web service	MA: Web service	Mono: Human	Bi: Human	
Process (1)	551	JServer	Business	Mecab	en	ja,en	
Process (2)	551	JServer	Business	Mecab	zh-CN	ja,zh-CN	
Process (3)	551	JServer	Business	Mecab	ko	ja,ko	
Process (4)	551	WebTranser	Business	TreeTagger	de	en,de	
Process (5)	551	GoogleTranslate	Business	TreeTagger	zh-TW	en,zh-TW	
Process (6)	551	WebTranser	Business	TreeTagger	pt	en,pt	
Process (7)	1,084	JServer	Univeristy	Mecab	en	ja,en	
Process (8)	1,084	JServer	University	Mecab	zh-CN	ja,zh-CN	
Process (9)	201	JServer	University	Mecab	ko	ja,ko	
Process (10)	179	JServer	Temple	Mecab	en	ja,en	
Process (11)	179	JServer	Temple	Mecab	zh-CN	ja,zh-CN	
Process (12)	179	JServer	Temple	Mecab	ko	ja,ko	
Process (13)	179	WebTranser	Temple	TreeTagger	de	en,de	
Process (14)	179	WebTranser	Temple	TreeTagger	fr	en,fr	

Table 2 The 14 translation processes used in the experiments that combine Web services (MT: machine translation service; Dic: bilingual dictionary service; MA: morphological analysis service) and human activities (Mono: monolingual human service; Bi: bilingual human service).

extremely high requirements for doing the translation/confirmation tasks. Only registered users who are of the translation expert level for the required two languages are accepted to do the tasks. Therefore, the quality of the bilingual users is guaranteed during the experiment.

Table 2 shows the 14 service processes of translation in the experiment. Each process is conducted using the three steps described in Table 1. Composite translation service in these processes has been developed with WS-BPEL specification [17] on the Language Grid[†]. Each process is realized by describing the human tasks in BPEL4People [18] and revising the composite translation service in the Language Grid. For example, Process (1) in Table 2 is a process for translating business related documents from Japanese to English. There are altogether 551 process instances in the experiment, each of which represents the task of translating a Japanese sentence to an English sentence. That means 551 subtasks for translation are available. The composite translation service uses three atomic services on the Language Grid: the JServer Japanese-English machine translation service, the business bilingual dictionary service, and the Mecab Japanese morphological analysis service. Human activities include post-editing tasks for English monolingual users and translation/post-editing tasks for Japanese-English bilingual users.

5. Observation and Analysis

Based on the experimental settings, we conduct several measurements to analyze how human activities affect QoS of the service processes.

(1) Functional QoS (translation quality: adequacy) and non-functional QoS (execution time and cost) for each step of the experiment for all the processes.

(2) Relationship between functional QoS (translation quality: adequacy) and non-functional QoS (execution time

and cost) for each step of the experiment for all the processes.

(3) Effects of variation of human activities on nonfunctional QoS attributes (execution time and cost) of Step 3 of each process.

We first define three indexes that are directly related to the quality of human activities: submission rate, acceptance rate and completion rate.

Monolingual Submission Rate (MSR): the percentage of pre-edited translation results in all the machine translation results for monolingual users in Step 2.

Monolingual Acceptance Rate (MAR): the percentage of accepted pre-edited translation results in all the submitted results for monolingual users in Step 3.

Monolingual Completion Rate (MCR): the percentage of completed pre-edited (submitted and accepted) in all the machine translation results for monolingual users in Step 3, which can be computed by $MCR = MSR \times MAR$.

The reason why we define the three index only for monolingual users lies in that the quality of bilingual users are totally guaranteed during the experiments as described in Sect. 4. Therefore, the submission rate, acceptance rate and completion rate can be regarded as 100% for bilingual users in this experiment. Table 3 shows the results of MSR, MAR, and MCR for all 14 processes in the experiments. From the result, we can see that the qualities of monolingual human activities of the processes differ much with each other.

5.1 Effects of Human Activities on Execution Time

We mainly measure the following items to study the effects of human activities on execution time of the service process.

Monolingual Work Time (MWT): execution duration of the human activities for monolingual users.

Bilingual Work Time (BWT): execution duration of the human activities for bilingual users.

Total Work Time (TWT): summation of monolingual work time (MWT) and bilingual work time (BWT), which

[†]http://langrid.org/service_manager/language-services/profile/ TranslationCombined WithBilingualDictionary



 Table 3
 Measurements of execution time for the 14 service processes.



Fig. 3 Relationship between time reduction rate and monolingual submission rate.

can be represented as TWT = MWT + BWT.

Common Work Time (CWT): execution duration when the process is a pure human translation process.

Time Reduction Rate (TRR): the percentage of execution time reduction when comparing with the common human translation process, which is calculated by $TRR = 1 - \frac{TWT}{CWT}$.

Figure 3 and 4 gives an analysis of the relationship between time reduction rate, monolingual submission rate and monolingual completion rate. All the data is based on the average calculation of one A4 size paper (about 700 Japanese characters or 400 English words) translation. With the participation of the human activities, the execution time of the translation task is reduced in half of the 14 processes and is increased in another half. The result also shows that high monolingual submission rate does not necessarily lead to high time reduction rate. However, there is a trend that higher monolingual completion rate leads to more reduction of execution time comparing with the common human translation process. We can also see that it might be difficult to reduce execution time when monolingual submission rate is relatively high while monolingual completion rate is low (Process (5), Process (8) and Process (9)). The reason lies in that there is much waste of time to deal with the submissions with low quality that are not accepted.



Fig. 4 Relationship between time reduction rate and monolingual completion rate.



Fig.5 Relationship between execution cost (monolingual work cost (MWC), bilingual work cost (BWC), total work cost (TWC)) and monolingual completion rate.

5.2 Effects of Human Activities on Cost

To study the effects of human activities on execution cost of the service process, we conduct the following measurements. In this experiment, bilingual users and monolingual users are paid by US\$50.00 and US\$5.00 per A4 page respectively. However, the payment is cut down to half for the results that are not accepted.

Monolingual Work Cost (MWC): cost of human activities for monolingual users, which is calculated by $MWC = 5.00 \times (MCR + \frac{1}{2}(MSR - MCR)).$

Bilingual Work Cost (BWC): cost of human activities for bilingual users, which is calculated by $BWC = 50.00 \times (1 - MCR)$.

Total Work Cost (TWC): summation of monolingual work cost and bilingual work cost, which can be represented as TWC = MWC + BWC.

Common Work Cost (CWC): work cost when the process is a pure human translation process, and CWC = 50.00.

Cost Reduction Rate (CRR): the percentage of cost reduction when comparing with the pure human translation process, which is calculated by $CRR = 1 - \frac{TWC}{CWC}$.



Fig. 6 Relationship between cost and translation quality.



Fig. 7 Relationship between execution time and translation quality.

Figure 5 shows the relationship between execution cost (monolingual work cost (MWC), bilingual work cost (BWC), total work cost (TWC)) and monolingual completion rate. The result shows that composite process by human activities and Web services is possible to reduce the translation cost comparing with the pure human translation cost, which supports the analysis in our previous preliminary experiments [16]. The reason lies in that parts of the work in the translation process is substituted with Web services and monolingual users with lower cost. Moreover, the result also shows that the cost reduction rate (CRR) becomes higher if the monolingual completion rate is higher. An extreme successful example is Process (3). Its cost reduction rate reaches 80.41% because of the high quality of the monolingual human activity with the monolingual completion rate 89.59%. The trend of the relationship will not change even if we change the unit cost of monolingual users and bilingual users, or change the calculation method of cost.

5.3 Effects of Human Activities on Relations of QoS Attributes

Figure 6 and Fig. 7 analyzes the relation between functional QoS dimensions (translation quality) and non-functional QoS dimensions (execution time and cost) by comparing different steps (Step 1 to Step 3 from the left to the right) for all the 14 processes in the experiment. The result shows that both execution time and cost increase from Step 1 to Step

3, which means that more time and cost are required to get higher functional QoS. For Step 1 that consists of Web services only, the cost and duration can be neglected comparing with those of human activities. However, the acquired functional QoS is also very limited. For Step 2 and Step 3 with the requirements of high functional QoS, the cost and execution time are much more.

Moreover, we categorize all the 14 processes based on the Monolingual Completion Rate (MCR), which directly reflects the quality of the monolingual human activities. The results in Fig. 6 and Fig. 7 also show that QoS attributes of a composite service are affected in different ways with different quality of human activities. For example, composite services with low quality of human activities (Process (2), Process (5), Process (8), Process (10)) cost largely to improve the functional quality from Step 2 to Step 3 and can only save small cost comparing with the pure human process (which is US\$50), and even require more execution time in Step 3 comparing with the pure human process (which is 100 min). However, composite services with high quality of human activities (Process (3), Process (4), Process (12), **Process** (13), **Process** (14)) can improve the functional QoS by inducing human activities with a tiny cost and execution time from Step 2 to Step 3. Therefore, quality of human activities affect the QoS attributes greatly. The result gives us an implication that we should propose quality control mechanisms for human activities to ensure high QoS for composite services.

5.4 Discussion

Although the example used in this paper falls into language service domain, the problem that absolute servicebased process cannot always meet users' requirements due to limitations in functional QoS dimensions do widely exist in many other domains, e.g., domains in travel plan recommendation service, automated image processing service and so on. To consider both functional QoS and non-functional OoS, composition of human activities and Web services can be regarded as a promising approach. In general, service implementation variety can be increased by composing human activities and Web services. Therefore, implications of the QoS analysis of language service composition by human and Web services are expected to be useful in above domains. However, it is necessary to consider how to design mechanisms of service composition based on different requirements from users because the effects of human activities and Web services are different for the whole workflow process. For pure Web service based processes with limited functional QoS, human activities can be introduced to improve functional QoS with different degrees according to users' requirements. For pure human processes, it is feasible to introduce Web services even with limited functional QoS to increase efficiency to improve non-functional QoS.

In this paper, we mainly focus on the analysis of the effects of human activities on functional QoS and nonfunctional QoS and therefore only use a few of the patterns for service composition defined in Sect. 3. However, it is important to consider how to apply different patterns of inducing human activities for different situations based on users' requirements since the effect of QoS for a service process might vary by a pattern. In the language translation example, the analysis of QoS effects of different patterns can be used for service design of field-based multi-language communication [19].

6. Related Work

Web service composition has been an important issue for past several years in the service-oriented computing area. Approaches of Web service composition include Petri nets, AI planning, formal model, semantic approach and so on [20]. Zeng et al. [1] propose a multidimensional QoS model for Web service composition including dimensions of execution price, execution duration, reputation, successful execution rate and availability. We also use QoS dimensions like execution cost and execution time as the nonfunctional QoS dimensions in our work. However, unlike our work, functional QoS dimensions are not considered in their work. Canfora et al. [21] are among the few who considers application-specific QoS together with general nonfunctional QoS. In their work, they use an example of image processing workflow where resolution and color depth are regarded as the application-specific QoS dimensions. However, their work concentrates on the overall QoS computing while our work deals with the issue of introducing human activites to improve functional QoS dimensions.

Human activities have been considered in workflow management. From the perspective of link of organization elements and business process, Zhao et al. [22] propose a formal model of human workflow based on BPEL4People specifications. They use communicating sequential processes (CSP) to model a human workflow consisting of basic elements of business process engine, task engine and people. However, they do not cover composition of human and Web services. There are also other researches on human workflow from the perspective of organization management [7] and resource management [8]. Comparing with their work, we induce human tasks into service processes from the perspective of QoS. Besides, crowdsourcing has been regarded as a promising means to reduce cost for conducting tasks. For example, crowdsourcing translation has been proposed for building corpus in the natural language process area [23], [24] with low cost, where quality management is an important issue. Although the above researches deal with the translation processes as our research does, they focus on discussing the possibility of replacing professional human translators with non-professional crowd workers while our research explores the variety of translation processes by composing Web services and human activities with analysis of the effects on QoS of composite services.

7. Conclusion

This paper proposes an approach of composing human activities and Web services considering both functional QoS and non-functional QoS of service processes. We conduct a large scale experiment in the domain of language translation to show that composing human activities and Web services brings variety to the traditional service processes and human processes. Further, we analyze the effects of human activities on QoS of service processes. We find out that human activities with high quality can significantly improve various QoS dimensions of the service processes, while human activities with low quality might have negative effects to the service processes. Our future work will mainly focus on unifying human services and Web services for solving issues in service composition.

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Donghui Lin was born in 1982. He received his Ph.D. degree in social informatics at Kyoto University in 2008. He is an assistant professor of social informatics at Kyoto University. His research interests include services computing, business process management and intercultural collaboration.



Toru Ishida was born in 1953. He is a professor of social informatics at Kyoto University. He has been working on Digital City and Language Grid projects. His research interests include autonomous agent and multiagent systems, semantic Web service and intercultural collaboration. He is a fellow of IEICE, IPSJ, and IEEE.



Yohei Murakami was born in 1978. He received his Ph.D. in informatics degree from Kyoto University in 2006. He is a researcher of social informatics at Kyoto University. His research interests lie in services computing and multiagent systems. He founded the Technical Committee on Services Computing in the Institute of Electronics, Information and Communication Engineers in 2009.



Masahiro Tanaka was born in 1981. He earned his Ph.D. in informatics from Kyoto University in 2009. He is a researcher at National Institute of Information and Communications Technology, Japan. He is currently working on services computing, focusing on runtime execution management of Web services. He also has experiences on development of infrastructures for Web service composition and service-based applications.