Improving Service Processes with the Crowds

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Abstract. With the development of service-oriented computing, more and more Web services are provided for users. 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). Meanwhile, the emergence of crowdsourcing makes various types of tasks done in more and more efficiency ways with low costs. To consider both functional QoS and non-functional QoS, in this paper we try to combine crowdsourcing activities with service processes. Further, this study aims at analyzing the effects of crowd activities on service processes in the real world. We use a case study in the domain of language service with a large scale experiment to show that composing crowd activities and Web services brings variety and creativity to the traditional service processes and human processes. From the experiments and analysis, we find out that quality of crowd activities is essential to service processes, and that crowd activities with high quality can significantly improve various QoS dimensions of the service processes.

1 Introduction

The power of crowds is bringing more and more opportunities for modern business. The emergence of crowdsourcing makes various types of tasks done in more and more efficiency ways with low costs. It is said that there is almost no limitation of crowd resources in crowdsourcing. There were reportedly more than 100,000 workers in over 100 countries (year 2007) in Amazon Mechanical Turk. The mobile crowdsourcing site Txteagle has 2.1 billion mobile phone subscribers across almost 100 developing countries. However, most crowdsourcing businesses are described as "humans doing human work" because people are just doing simple work with low salaries there. In service oriented platforms, it becomes necessary to compose crowd activities with services to bring creativity to the traditional service-based business processes.

In QoS-aware service composition, general QoS dimensions are always defined, including execution cost, execution time, 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 [1,2,3]. However, application-specific QoS

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dimensions might also be essential in many cases. In the case of translation services, users care about the translation quality[1] rather than general dimensions. Therefore, it is important to keep the translation quality while considering the improvement of other QoS dimensions.

To address the above issue, combining Web services and human activities is expected to be a promising solution. A good example in language service domain is that translation work can be done by composing machine translation services, monolingual crowd users and bilingual crowd users. As a first step, we conducted a preminalary experiment [5] to show the effectiveness. However, the problem is that human activities might be the bottleneck if human resources are not sufficient or human task quality cannot be guaranteed. Therefore, in this paper we try to use the crowdsourcing approach to improve service processes, considering both functional QoS and non-functional QoS: service-based processes are efficient; human participation guarantees functional QoS; crowdsourcing brings cost reduction.

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

2 Motivation Example

In this section, we show an example of language translation. To provide flexible language services, we developed the Language Grid [6], which has been collecting language resources from the Internet, universities, research labs and companies. All the language services are wrapped from language resources by standard Web service interface. Using the atomic Web services, we have also developed a series of composite services[2]. Figure 1 shows a composite machine translation service which combines services including morphological analysis service, dictionary service, machine translation service and so on. By combining dictionary services and other services, the translation quality can be improved.

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, composite service in Figure 1 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. To study this problem, we conducted a preminalary trial to combine human activities and

[1] In the language service domain, translations were evaluated on the basis of adequacy and fluency in previous reports [4].

[2] http://langrid.org/service_manager/language-services

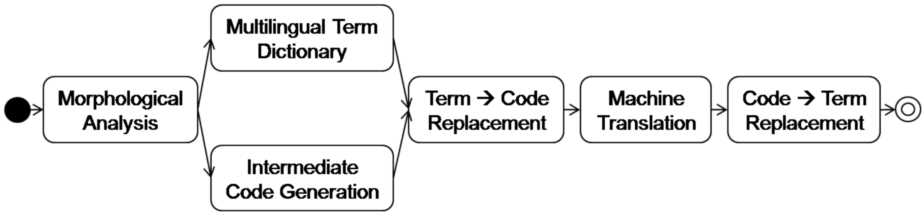

Fig. 1. A composite machine translation service provided by the Language Grid.

Web services [5] with a small scale experiment. However, we found that human might also be the bottleneck if human resources cannot be assured or human task quality cannot be guaranteed. Therefore, we consider combining crowdsourcing activities into service process. Although this example falls into the language service domain, the problem that pure service-based processes cannot always meet users' requirements due to limitations in functional QoS dimensions do widely exist in many other domains.

3 Composition of Web Services and Crowd Activities

Considering that there is an existing service process, crowd 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. Moreover, the crowd activities can also be introduced into a process composed by crowd activities and Web services using the same approach. There are following basic types for introducing a crowd activity into a service process for improving certain QoS dimensions $Q^S(s)$.

- *Complete substitution*: a crowd activity ca_i is used to substitute a service s_i (or a subprocess) completely, i.e., $(Q^S(ca_i) > Q^S(s_i)) \to S(s_i, ca_i)$ ($S(a,b)$ denotes the substitution of a by b for any a and b).
- *Partial substitution*: a crowd activity ca_i is used to form a selective control relationship with a service s_i (or a subprocess) under condition C, i.e., $(Q^S((s_i, ca_i, C)) > Q^S(s_i)) \to S(s_i, (s_i, ca_i, C))$.
- *Pre processing*: a crowd activity ca_i is used to process the input of a service s_i or (or a subprocess), i.e., $(Q^S((ca_i; s_i)) > Q^S(s_i)) \to S(s_i, (ca_i; s_i))$.
- *Partial pre processing*: a crowd activity ca_i is used to process the input of a service s_i or (or a subprocess) under condition C, i.e., $(Q^S((ca_i; s_i, C)) > Q^S(s_i)) \to S((s_i, (ca_i; s_i, C)))$.
- *Post processing*: a crowd activity ca_i is used to process the output of a service s_i (or a subprocess), i.e., $(Q^S((s_i; ca_i)) > Q^S(s_i)) \to S(s_i, (s_i; ca_i))$.
- *Partial post processing*: a crowd activity ca_i is used to process the output of a service s_i (or a subprocess) under condition C, i.e., $(Q^S((s_i; ca_i, C)) > Q^S(s_i)) \to S(s_i, (s_i; ca_i, C))$.

We use the example of composite translation service in Section 2 (Figure 1) to explain the above types of forms. For the 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 crowd activities to improve $Q^S(p)$ to meet the condition $Q^S(p) \geq Q_u$ using one or more approaches from the following possible alternatives.

- Substitute the machine translation service process p with a crowd activity for translation ca to make $Q^S(ca) \geq Q_u$;
- Introduce a crowd activity of modification ca for pre processing 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 to make $Q^S((ca; p)) \geq Q_u$;
- Introduce a crowd activity of modification ca for post processing the output translation result (e.g., improve the fluency of the result by a monolingual user) with condition $C = (Q^S(p) \geq Q^*)$ into machine translation service process p to make $Q^S((p; ca, C)) \geq Q_u$.

Figure 2 shows an example of service process for translation that combines a composite Web service for translation and crowd services. *Composite Translation Service* indicates the atomic machine translation service or composite machine translation service provided on the Language Grid as shown in Figure 1. For crowd activities, monolingual users and bilingual users can be considered in the translation processes: monolingual users modify the translation results of the machine translation services, while bilingual users confirm the modification results and also translate the contents that cannot be modified by the monolingual users. Two types of HITs (human intelligence tasks)[3] are distributed for crowdsourcing.

4 Experiment

To observe and analyze how crowds could improve service processes, we conduct a large scale experiment for language translation. Our experiments are based on the translation processes that are composed by crowd services and Web services described in Section 3. Settings of QoS measurement, processes, process instances, Web services and crowd services are as follows.

QoS in the language service domain consists of non-functional QoS dimensions (cost, execution time, etc.) and functional QoS dimensions (translation quality: fluency and adequacy). In this experiment, we want to study how crowd services can help improve the non-functional QoS while keeping the same functional QoS. Therefore, we mainly evaluate the execution cost (in *US*\$) and execution time (in *minute*) of the processes.

[3] HIT is used by Amazon Mechanical Turk for description of a human task in the crowdsourcing. We borrow this concept when describing a crowdsourcing task.

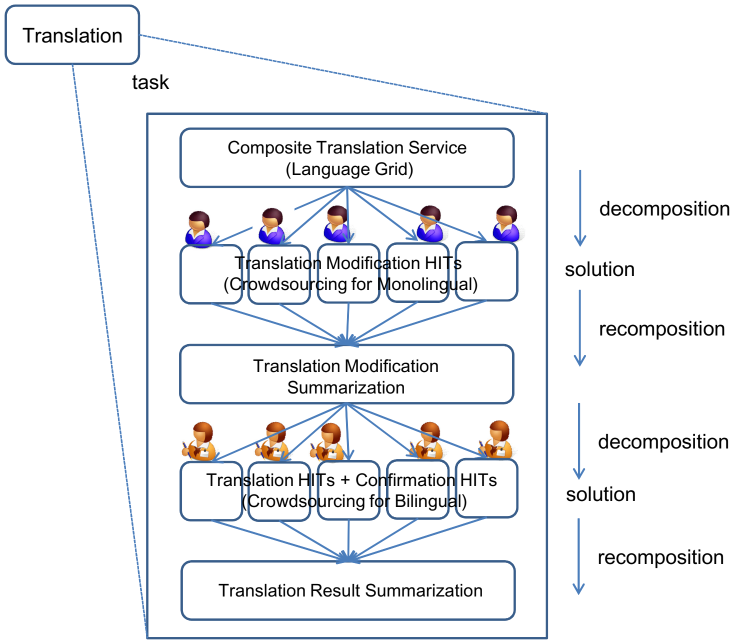

Fig. 2. An example of service process for translation that combines a composite Web service for translation and crowd services.

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

- Machine translation services: Web services by wrapping language resources of JServer machine translation service (Japanese (ja) ↔ English (en), Japanese (ja) ↔ Korean (ko), Japanese (ja) ↔ Simplified Chinese (zh-CN) and Japanese (ja) ↔ Traditional Chinese (zh-TW)) provided by Kodensha Co., Ltd, GoogleTranslate translation service (English (en) ↔ Traditional Chinese (zh-TW)) provided by Google, WebTranser machine translation service (English (en) ↔ German (de), English (en) ↔ French (fr), English (en) ↔ Spanish (es), and English (en) ↔ Portuguese (pt)) provided by Cross Language Inc.
- 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.
- 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 crowdsourcing tasks are included in the experiment, conducted by translation modification monolingual users and translation/confirmation bilingual users. To study how the quality of crowd activities affects QoS of service processes, we use two different settings for the two types of crowdsourcing tasks.

- Crowdsourcing for monolingual users: low requirements for doing the translation modification 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 before the experiment.
- Crowdsourcing for bilingual users: 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 crowd activity is guaranteed before the experiment.

Table 1. 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 crowd activities (Mono: monolingual human service; Bi: bilingual human service).

Process	HITs	Services in the Process				
		MT	Dic	MA	Mono	Bi
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 1 shows the 14 service processes of translation. The control flow of each process has been shown in Figure 2. Composite translation service in these processes has been developed with WS-BPEL specification [7] on the Language Grid[4]. Each process is realized by describing the human tasks in BPEL4People [8] and revising the composite translation service in the Language Grid. For example, **Process (1)** in Table 1 is a process for translating

[4] http://langrid.org/service_manager/language-services/profile/TranslationCombinedWithBilingualDictionary

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 HITs are available for crowdsourcing. 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. Crowdsourcing tasks include translation modification HITs for English monolingual users and translation/confirmation HITs for Japanese/English bilingual users.

5 Observation and Analysis

Based on the experimental settings, we conduct several measurements to analyze how crowd activities affect QoS of the service processes. We first define three indexes that are directly related to the quality of the crowdsourcing tasks: submission rate, acceptance rate and completion rate.

- Monolingual Submission Rate (MSR): the percentage of submitted HITs in all the HITs for monolingual users.
- Monolingual Acceptance Rate (MAR): the percentage of accepted HITs in all the submitted HITs for monolingual users.
- Monolingual Completion Rate (MCR): the percentage of completed HITs (submitted and accepted) in all the HITs for monolingual users, 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 before the experiments as described in Section 4.1. Therefore, the submission rate, acceptance rate and completion rate can be regarded as 100% for bilingual users in this experiment.

5.1 Effects of Crowd Activities on Execution Time

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

- Monolingual Work Time (MWT): execution duration of the crowdsourcing tasks for monolingual users.
- Bilingual Work Time (BWT): execution duration of the crowdsourcing tasks for bilingual users.
- Total Work Time (TWT): summation of monolingual work time (MWT) and bilingual work time (BWT), which can be represented as $TWT = MWT + BWT$.
- Common Work Time (CWT): execution duration when the process is a common 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 $TRR = 1 - \frac{TWT}{CWT}$.

Table 2. Measurements of execution time for the 14 service processes

Process	MSR	MAR	MCR	MWT	BWT	TWT	CWT
Process (1)	47.77%	92.13%	44.01%	21.43 min	102.86 min	124.29 min	166.29 min
Process (2)	46.04%	48.39%	22.28%	23.60 min	128.57 min	152.17 min	116.57 min
Process (3)	94.01%	95.30%	89.59%	25.71 min	16.29 min	42.00 min	116.57 min
Process (4)	100.00%	63.53%	63.53%	27.60 min	53.14 min	80.74 min	116.57 min
Process (5)	78.89%	25.32%	19.97%	35.14 min	137.14 min	172.28 min	116.57 min
Process (6)	99.63%	54.07%	53.87%	34.86 min	53.14 min	88.00 min	116.57 min
Process (7)	52.79%	61.40%	32.41%	18.91 min	129.09 min	148.00 min	127.27 min
Process (8)	71.79%	24.52%	17.60%	17.03 min	101.82 min	118.85 min	78.18 min
Process (9)	98.70%	38.73%	38.23%	22.50 min	56.25 min	78.75 min	78.15 min
Process (10)	45.59%	27.33%	12.46%	19.44 min	213.33 min	232.77 min	166.67 min
Process (11)	40.08%	83.43%	33.44%	14.44 min	120.00 min	134.44 min	133.33 min
Process (12)	75.28%	87.60%	65.95%	22.78 min	60.00 min	82.74 min	133.33 min
Process (13)	95.01%	64.32%	61.11%	19.44 min	60.00 min	79.44 min	133.33 min
Process (14)	90.82%	78.45%	71.25%	26.67 min	60.00 min	86.67 min	133.33 min

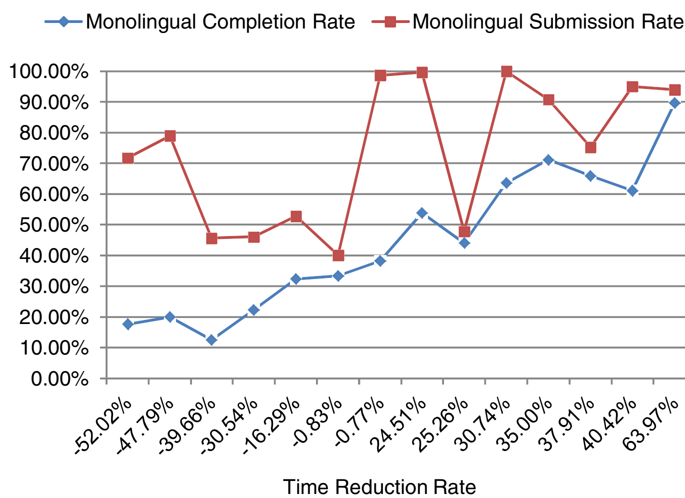

Fig. 3. Relationship between time reduction rate, monolingual submission rate and monolingual completion rate

Table 2 shows the result related to execution time of all the processes in the experiment. All the data is based on the average calculation of one A4 size paper (about 700 Japanese characters or 400 English words) translation. Moreover, monolingual submission rate, monolingual acceptance rate and monolingual completion rate are also acquired, which are based on the average data of all monolingual users who are involved in each process. From the result in Table 2, we can see that the qualities of crowdsourcing tasks of the processes differ much with each other. With the participation of the crowdsourcing activities, the execution time of the translation task is reduced in half of the 14 processes and is increased in another half.

Figure 3 gives a deeper analysis of the relationship between time reduction rate, monolingual submission rate and monolingual completion rate. The result 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. Table 2 and Figure 3 also shows 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.

5.2 Effects of Crowd Activities on Cost

To study the effects of crowd 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 HITs that are not accepted.

- Monolingual Work Cost (MWC): cost of the crowdsourcing tasks for monolingual users, which is calculated by $MWC = 5.00 \times (MCR + \frac{1}{2}(MSR - MCR))$.
- Bilingual Work Cost (BWC): cost of the crowdsourcing tasks 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 common human translation process, and $CWC = 50.00$.
- Cost Reduction Rate (CRR): the percentage of cost reduction when comparing with the common human translation process, which is calculated by $CRR = 1 - \frac{TWC}{CWC}$.

Figure 4 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 crowdsourcing activities and Web services is possible to reduce the translation cost comparing with the common human translation cost, which supports the analysis in our previous preliminary experiments [5]. 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 crowd 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.

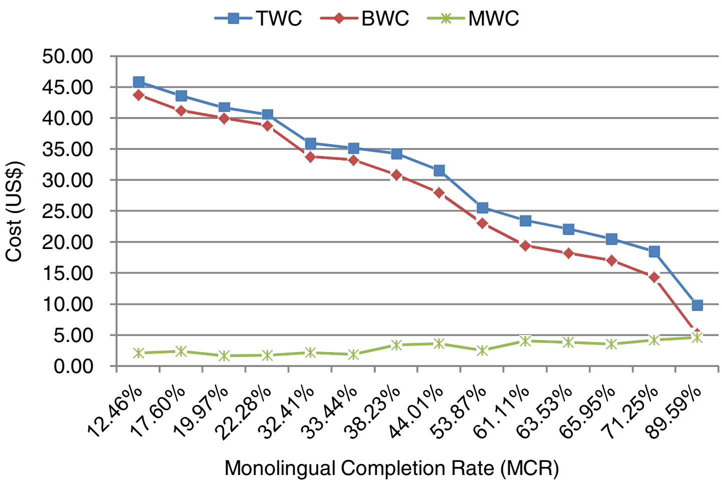

Fig. 4. Relationship between execution cost (monolingual work cost (MWC), bilingual work cost (BWC), total work cost (TWC)) and monolingual completion rate

5.3 Discussion

In this paper, our case study and experiments are in the language service domain. However, the result has its generality since it can reveal the relationship between crowd activities and QoS of service processes. The spectrum of process ranges from service process to human process. The non-functional QoS of service process is generally high (with low execution cost and execution duration) because of its automation and efficiency. However, functional QoS is rather limited because of the application-specific factors. On the other hand, human process can obtain higher functional QoS but lower non-functional QoS, because human can handle the application-specific limitations flexibly with the loss of efficiency. Using monolingual users and bilingual users to compensate the limitations of machine translation services is a good example. To cover both dimensions of QoS, composition of crowd activities and Web services can be regarded as a promising approach.

Based on the analysis, we find out that composition of crowd activities and Web services is possible to be utilized in two directions: composing crowdsourcing tasks into service-based processes and composing services into human-based crowdsourcing activities. For service processes with limited functional QoS like machine translation service, crowd activities can be introduced to improve the functional QoS according to users' requirements. For human-based crowdsourcing activities, it is also feasible to introduce Web services even with limited functional QoS to increase the efficiency to improve non-functional QoS while keeping high functional QoS. However, both directions are currently lack of theoretical and practical foundations because evaluation and prediction of functional QoS and non-functional QoS will be more difficult if there are human activities. Therefore, it is important to consider how to aggregate different dimensions of

QoS from both human activities and Web services when utilizing the composition. Our work can be regarded as a preminalary study in the directions.

6 Related Work

Web service composition has been an important issue for past several years in the service-oriented computing area. Recently, QoS-aware service composition has become the focus in this area [1,2,3]. 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 duration as the QoS dimensions in our work. In workflow management area, human task has been studied. From the perspective of link of organization elements and business process, Zhao *et al.* [9] propose a formal model of human workflow based on BPEL4People specifications. They use CSP process algebra 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 [10] and resource management [11]. Comparing with their work, we introduce human activities into service processes from the perspective of QoS. Our research uses the crowdsourcing approach for improving QoS of service processes and conduct large scale experiments in the real world for analyzing the composition of crowd activities and Web services.

7 Conclusion

This paper proposes an approach of composing crowd 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 crowd activities and Web services brings variety and creativity to the traditional service processes and human processes. Further, we analyze the effects of crowd activities on QoS of service processes. We find out that crowd activities with high quality can significantly improve various QoS dimensions of the service processes, while crowd activities with low quality might have negative effects to the service processes. Our future work will mainly focus on unifying crowd services and Web services for solving issues in service composition. We also aim at designing the coordination mechanisms for managing crowd activities in service processes, and controlling the interaction between crowds and services.

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