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A Web-Based Platform for User-Interactive Question-Answering

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Abstract A user-interactive question-answering (QA) platform named *BuyAns* (at www.buyans.com) is presented. The platform is a special kind of online community and mainly features a rewarding scheme for answering questions among all users, a pattern-based user interface (UI) for questioning and answering, and a pattern-based representation and storage scheme for accumulated question-answer pairs. The system actually proposes and promotes a C2C business model for exchanging and commercializing knowledge from ordinary people. It can also be used as an incentive and collaborative approach to knowledge acquisition. Driven by the business model, prompt and quality answers are quickly accumulated. Due to the patterns used, accurate answers can be provided automatically for repeated questions. Facilitating features and technologies, including user modeling, reputation management, and answer clustering and fusion, are also developed and briefly described. Preliminary user studies show the potential attraction of the system to its users as well as reasonable usability and user-satisfaction. We anticipate hot applications of such a system in the Web 2.0 era.

Keywords question answering · user-interactive QA system · C2C business model · knowledge acquisition · web community · web 2.0

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1 Introduction

The Web is increasingly becoming an ideal source of answers to various domain-independent questions because of the tremendous amount of information that is now available online. Search engines (such as Google[1]) are frequently used tools for people to find their needed information on the Web. However, the accuracy and relevancy of their returned results are still not satisfied in many cases. Hence, question answering (QA) systems (such as Ask Jeeves[2]) are more preferable, which are expected to automatically understand a user's questions and return the exact answers. Although the objective is good and promising, by mimicking the metaphor of the natural QA scheme for direct access of answers, the accuracy of current QA systems is still much dependent on the artificial intelligence (AI) of computer systems, which is far from satisfactory in many cases. Hence, automatic QA systems still cannot outperform search engines. This is why there is no QA system running on the Web which is as popular as Google. We claim that automatic QA is just another effort of AI, which tries to achieve automatic information retrieval but still cannot solve the fundamental problem of current information retrieval technology: precision/recall.

Moreover, these efforts can only retrieve information that is already available on the Web (or the cyber world), but cannot acquire the information or knowledge that is currently not available online. Certain questions can only be answered by human experts. Hence, in order to facilitate acquisition or exchange of such information or knowledge, we develop a Web-based user-interactive QA system, which is called *BuyAns* [1]. Actually, the system can be used as a collaborative approach to knowledge acquisition. As more knowledge is accumulated and well represented, more accurate automatic question-answering is possible. It is an application of Web 2.0 [2], which harnesses collective intelligence from all users and trusts them as developers to gradually make the system richer with data or knowledge.

In fact, there are already some Web communities, like BBS and various forums, which can be used to exchange comments, opinions, or in general, information. Knowledge, as a special kind of information, can also be exchanged and shared in such Web communities. Users can ask questions and get answers from other users, usually, for free. However, people, especially, professionals, are usually busy. They can sometimes volunteer to answer some questions to share their knowledge, but not always. This is because the cost of answering those questions is their time, which is also precious. However, if they can get some kind of rewards, e.g., money, by answering the questions, they should be more willing to spend their valuable time. In such cases, their time and knowledge are rewarded. This is actually an economic principle and our motivation and assumption to develop *BuyAns*. We believe there are many (professional) people who would like to pay for their urgent questions and there are more people who know the answers and would like to spend some time to provide the answers, as long as their rewards are greater than their costs. Hence, we believe such systems will have a very promising marketplace.

BuyAns, as a rewardful user-interactive QA system, proposes and promotes a C2C business model for commercializing ordinary people's knowledge. The system provides a convenient marketplace on the Web for knowledge trading, where ordinary people can place an order for answers (knowledge) to their questions by offering some money for potential answers on the one hand and also earn some money from answering other people's questions on the other hand.

[1] http://www.google.com/

[2] http://www.ask.com/

The accumulated answers in the system, if well archived and formalized in a global knowledge database, can be reused later. Especially, if some users ask for the same or similar questions, the system can automatically provide the correct answers. However, the questions and answers in natural language format are not easy to be understood by machines, though relatively easy by human beings. If not well represented, the accumulated answers are just like the current Web documents and are not easy to be utilized. Hence, in order to make the questions and answers understandable for both machines and human beings, we propose a pattern-based UI for asking and answering. A question pattern is a generalized form of a class of questions which are not only similar in structure but also relevant in semantic concepts. Each variable part in a particular pattern is annotated by a semantic label, which is used to not only remind users to fill in correct text when using it but also let machines know the semantics of the filled-in text. Hence, we also call it semantic question pattern. In addition, the accumulated questions and answers are represented and stored in such a pattern-based format, which is possible to be converted with least effort to formal knowledge representation for efficient machine understanding, processing, and reasoning. In such cases, the system with its accumulated knowledge can be used as some kind of search engines with exactly matched results, or at least as some complement to the current search engines.

BuyAns can serve as a platform for knowledge acquisition for various applications involving many users. Especially, it can be used as a platform for technical support or employee continuous training for companies. End-users of a company's products can help one another on the platform such that the workload of technical support staff can be reduced dramatically and therefore the corresponding cost can be saved. New employees' questions related to their jobs can be answered by their senior colleagues and the internal knowledge of the company can be acquired and accumulated as a by-product. In order to support or facilitate these features, other technologies, including user modeling, reputation management, and answer clustering and fusion [7], are also developed and will be briefly described in this paper.

The remainder of the paper is organized as follows: Section 2 presents related work. Section 3 presents the system architecture of *BuyAns*. Main functions and user interfaces of the system are presented in Section 4. The application issues including possible business models and users studies are presented in Section 5. Section 6 concludes the paper and discusses future work and potential issues.

2 Related work

Search engines can actually be regarded as a special kind of QA systems, and to certain extent, can be used as a convenient and fast means to obtain knowledge (or information in general) on the Web. A user can ask a question in the form of keyword(s) in a search engine, which in turn, provides the user with answers in the form of links. One of the advantages of search engines is their immediate response to the user's query (question). However, search engines usually return a lot of links of Web documents but still cannot guarantee the relevancy to the user's question. The user still has to take some time to find the right answer by himself/herself from the search result.

In this sense, automatic QA systems are developed with the exact goal of returning a concise answer to a question rather than a list of documents. Especially, the Text Retrieval Conference (TREC) Series has greatly motivated QA research in recent years. In TREC8, TREC9, TREC10, a QA system is required to return 5 ranked answers evaluated by MRR

metric for each test question [8]. In TREC11, a QA system is required to return only one exact answer for each test question. The QA systems in TREC12 and TREC13 are required to return either a document extract (not longer than 250 characters) believed to contain an answer to the question or the "NIL" used to indicate the systems' belief that there was no correct answer in the collection [9].

Due to the low accuracy of automatic systems, interactive QA systems are especially useful. Potentially, all online forum systems can be used for user-interactive QA. There are also several specially designed user-interactive QA systems, among which Google Answers [3] was the most famous one. It was designed based on the following assumption: if an ordinary person is just to get the answer of a question, it is better to ask an expert than to search by himself/herself. Google Answers recruited a group of researchers, who were tested and trained to be experts at locating hard-to-find information resources on and off the Web. A registered user could post his/her questions to Google Answers; and he/she should specify how much money he/she was willing to pay to get the answers. Google Answers limited the price to be between $2 and $200 and this payment was refundable if the asker was not satisfied with all of the answers. Furthermore, Google Answers charged a non-refundable fee of $0.5 for each question. The question posted would be answered by a Google expert, who would earn the money offered for the question if the answer was satisfactory to the asker. Finally the asker could be informed of the answer by email. All the questions could be publicly viewable on the Google Answers Website so that others could add their comments. However, a normal registered user could only add his/her comments but could not earn the money by providing his/her answers. Google Answers gathered a rich collection of answers to various questions in many fields. A user could search and view the database for the solved questions free of charge. This was indeed a very good way to share and retrieve knowledge. However, it finally failed due to its strict policies. The price range between $2 and $200 was too strict. $1 or even $0 may give more people opportunities to try it and give it more opportunities to succeed. Another reason is that Google Answers was not a true Web 2.0 Website. Only a limited number of so-called experts were not enough to answer all the questions. No opportunity was given to normal users and other "experts". Hence, there was no real competition. There should be many other normal users who could provide better answers than those "experts". Hence, on the contrary, Yahoo! Answers [6], though launched much later, is very successful due to its more flexible strategy.

Sina iAsk [4] is another promising user-interactive QA system, which mainly targets at the Chinese community. Unlike Google Answers, Sina iAsk is not directly money-driven. Posting a question on iAsk does not cost any actual money. Everyone is voluntary to help others to get their answers. Similar to Yahoo! Answers, what a user can gain is the credit in the cyber-community. However, the credit a user earns in iAsk is associated with the user's community portal in Sina[3], so that he/she can also change his credit for some prizes. There is no corresponding researcher or expert role in Sina iAsk. Every registered user could post his questions and answer others' questions freely. Therefore, the question asker should bear the risk that the quality of the answers may not be high. However, this issue may not be too serious, since the asker usually needs to know only the basic idea so as to solve his/her problem. Other users' answers/comments, even though with low quality, can still bring in some valuable hints to the asker. Furthermore, Sina iAsk also invites many expert agencies from various domains to join the system. For example, several law firms are invited to participate in problem solving related to law issues. These expert agencies are motivated to

[3] http://www.sina.com.cn/

answer related questions since they can make free advertisements in their answers. The system also keeps a digest for the answered questions, which is a very good knowledge repository for all Web users. Hence, in general, Sina iAsk achieves a pretty good user satisfaction. Baidu Zhidao [5] is probably the most popular user-interactive QA service in China though it was launched later than Sina iAsk since it is associated with, and serves as a very good complement to, the Baidu search engine[4]. Many other companies, including Microsoft[5], Amazon[6], and Tencent[7], have also launched similar services recently. Hence, we believe that our idea proposed 4 years ago is nearly coming true that QA is one of the next hot Internet applications.

Compared with the above-mentioned interactive QA systems, our *BuyAns* system features considerable new business models to encourage both active participation of users and high quality of knowledge acquired. *BuyAns* also features many novel functions and user interfaces, including those for pattern-based questioning and answering, and for answer clustering and quality assessment. These functions and user interfaces can further facilitate high quality knowledge acquisition.

For the purpose of collaborative knowledge accumulation and management, the Knowledge Grid [11] is an intelligent, sustainable Internet application environment that enables people or virtual roles to effectively capture, publish, share, and manage explicit knowledge resources [12]. In the environment of knowledge grid, our QA system can act as a recommender system to provide content from users to users based on the users' models. Zhuge's Knowledge Space Model [16] is also a good candidate for building the knowledge base of formal knowledge extracted from the pattern form question-answer pairs in our system.

3 System architecture

The system architecture of *BuyAns*, which is shown in Figure 1, contains the User Interface for users to interactively post and browse questions/answers (Q/A), the Content Analyzer, the Search module, the Answer Clustering and Quality Assessment module, the User Management module, the Pattern Database, the Current Q/A Database (storing all unsolved questions and their current answers arranged in different boards/categories), the Accumulated Q/A Database (for historical questions with correct answers), and the Knowledge Base.

A typical user scenario is as follows. A user uses a pattern (or not) to post a question (with an amount of money as an offer) for correct answer(s) using the User Interface. The Content Analyzer accepts the question and distributes it to the corresponding board in the Current Q/A Database. The user can also manually select a suitable board to host the question. At the same time, the Content Analyzer also automatically sends the question to the Search module, which first tries to obtain an answer from the Knowledge Base by searching and inference, and if fails, tries to search for similar questions in the Accumulated Q/A Database and return their associated correct answers. The answers automatically obtained are associated with the question and displayed in the corresponding board. All other users can visit the board and see this question, and if they want, can manually post their answers to this question, using the suitable pattern or not. The questioner (asker) user can browse all the answers (both

[4] http://www.baidu.com/

[5] http://www.microsoft.com/

[6] http://www.amazon.com/

[7] http://www.tencent.com/

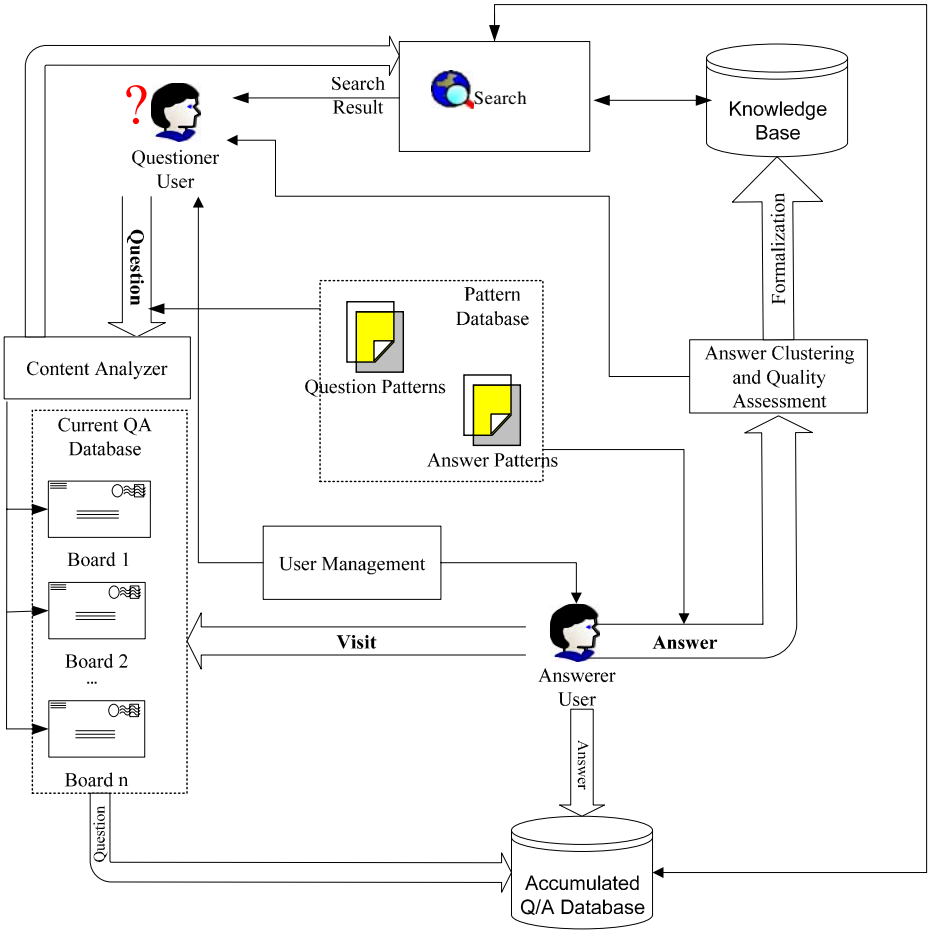

Figure 1 System Architecture of *BuyAns*.

automatically found by the Search module and manually posted by other users) to his/her question and select the first/earliest correct answer (or several correct answers) as the final correct answer based on his/her judgment. If there is no dispute, the money offered by the asker will be paid to the provider(s) of the correct answer(s) after deducting a corresponding commission fee for the system. If a correct answer selected is found automatically from the Accumulated Q/A Database, its previous provider can still earn the offered money though the commission fee to the system may be higher. The Answer Clustering and Quality Assessment module helps cluster similar/relevant answers into several groups and provide overall quality for each answer and each group based on the answerers' capabilities and reputations and the timeliness of the answers. The clustering and fusion result can greatly facilitate the asker to browse the answers and select the correct one(s) efficiently. The question and its correct answer (s) determined by the asker are associated and stored in the Accumulated Q/A Database as a Q/A pair. Hopefully, these high quality Q/A pairs are formalized and converted to formal knowledge and stored in the Knowledge Base for future auto-answering.

The User Management module is responsible for computing and managing user models, including their interests, authorities (capabilities and experiences), reputations, and financial

transactions. It also includes functions of facilitating dispute settlement between askers and answerers.

4 Main functions and user interfaces

The *BuyAns* system features many new functions and user interfaces. In this section, we only briefly present four of them: (1) Pattern-based QA Process; (2) Automatic Answering of Repeated or Similar Questions; (3) User Modeling; (4) Answer Clustering and Quality Assessment. Other functions, including knowledge extraction from pattern-based Q/A pairs, will be developed in the future and presented in separate papers.

4.1 The pattern-based QA process

Pattern, or semantic question pattern, is a unique feature of our QA system. A (semantic question) pattern is a generalized form of a class of questions which are not only similar in structure but also about similar semantic concepts. Each variable part (also referred to as a place-holder) in a particular pattern is annotated by a semantic label, which is used to not only remind users to fill in correct text when using it but also let machines know the semantics of the filled-in text. Hao *et al.* [17] have presented a previous version of the definition of the patterns and related applications in detail. An automatic generation method is also proposed and implemented by them [18], which can generate high-quality semantic patterns based on a set of free-text questions using an entropy-based model. In this paper, we briefly introduce the main idea of the patterns and focus on their updated version and new applications.

When a user wants to post a question, he/she may use free text to express it. Alternately, he/she can select a suitable pattern and just fill the specific content of his/her question in the variable parts. The patterns can reduce the ambiguity of the questions and enhance machine understanding of the questions. Both machines and human beings can know what type of information the question is asking for from the pattern used. For example, if a user wants to ask: "How to say "你好" in English?" he/she may choose the pattern "<Q>How</Q> to say [entity\word] in [entity\language] ?" and fill in the place-holder "[entity\word]" with "你好" and the place-holder "[entity\language]" with "English". We can know from the pattern that "你好" is a word and "English" is a language. The answer pattern is even simpler: "[entity\word]", which means that the answer should be exactly a word (or a phrase) that specifies the expression of "[entity\word]" in the corresponding language.

Figure 2 and Figure 3 briefly illustrate how to use a pattern to ask and answer questions. Its procedure consists of the following three steps.

Step 1: category selection

All question patterns are categorized in a global Ontology. In the current version, question patterns are categorized according to the semantic labels of the expected answers. For example, the question pattern "<Q>How</Q> to say [entity\word] in [entity\language] ?" is listed in the category "entity" and subcategory "word" since the expected answer is a word (or a phrase). Hence, the asker should select category "entity\word" in this step in order to find the above mentioned question pattern.

Step 2: pattern selection

In the selected category, there may be many question patterns. The asker should select a suitable one for his/her question and the pattern will be converted to a user friendly Web form with blanks (textboxes) for the asker to fill in his/her specific question content.

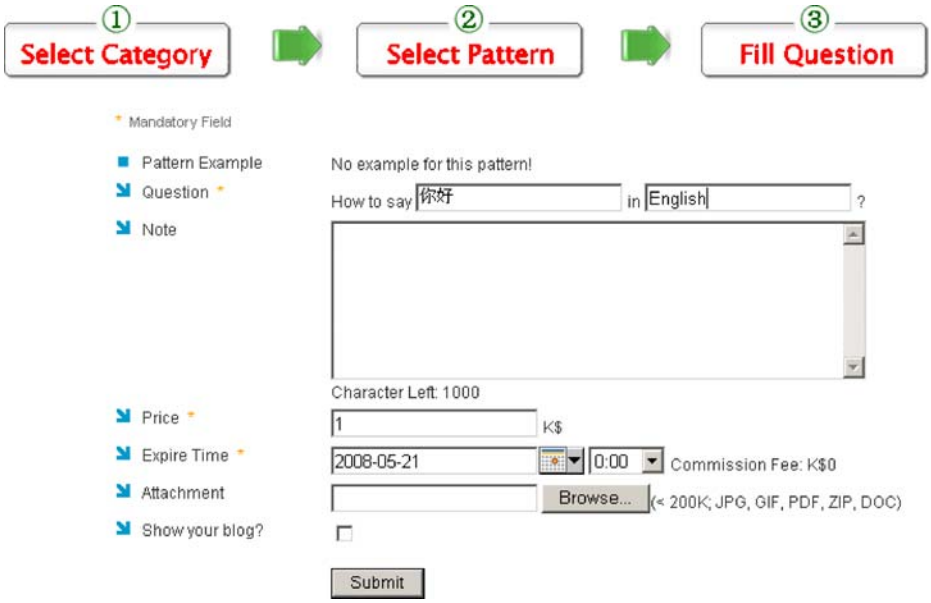

Figure 2 The user interface for asking a pattern form question.

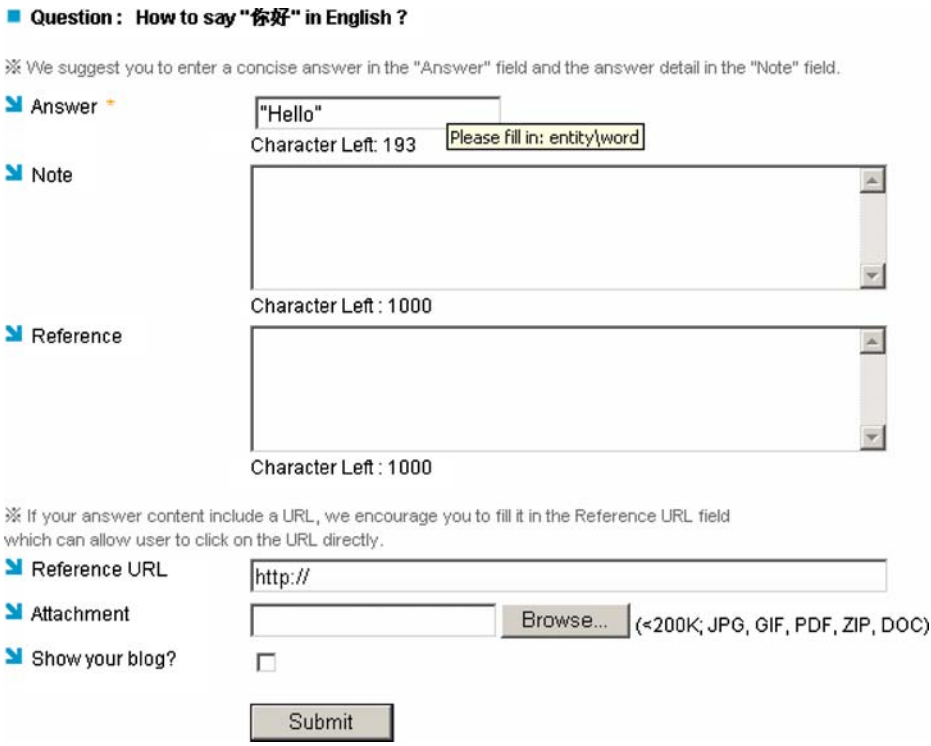

Figure 3 The user interface for answering a pattern form question.

Step 3: question filling

For the above mentioned question, its generated form contains two textboxes with hovering text "entity\word" and "entity\language", which indicate the types of content required. The asker only needs to fill "你好" and "English" in the textboxes, respectively. If he/she wants to add more constraints or explanations to his/her question, the comment textbox below the question is for this purpose, as shown in Figure 2.

When another user answers this question, the system retrieves the answer pattern associated with the question pattern and displays the answer form as shown in Figure 3. Again, the answerer only needs to fill the required type of content (i.e., a word) in the textbox, e.g., "hello" or "hi", based on his/her knowledge. Additional information may be filled in the comment textbox. The questions and answers accumulated in this way are also stored in the database in the same pattern form. Hence the pattern form is also the storage scheme for question-answer pairs in our database. Through the patterns, the system can extract the required information from the accumulated question and answers more accurately, without much reliance on Natural Language Processing (NLP).

Although a pattern form question is easier for machines to understand, it is not as convenient as a free-text-form question for human users, at least for novice users, to use for questioning. Hence, we also provide a function to automatically suggest a much shorter list of patterns for the user to choose. When a user posts a question in free text, the system searches the pattern database to retrieve relevant patterns according to the structure of the question. The suggested list of relevant patterns ranked by relevancy is then returned to the user, as shown in Figure 4.

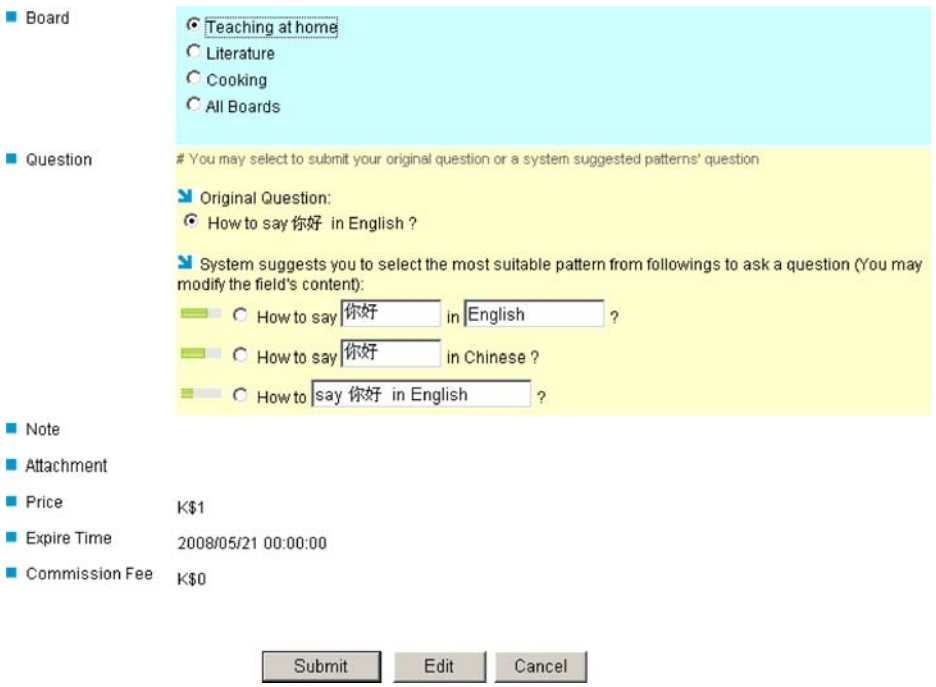

Figure 4 The user interface for pattern suggestion.

4.2 Automatic answering of repeated or similar questions

Some repeated questions are frequently asked. To answer them manually again and again is not an economic way. It is even a boring task for customer service staff. Our system can answer repeated questions automatically with historical correct answers in the Accumulated Q/A Database based on our semantic question patterns [17] which we encourage users to use. By doing so, askers can obtain immediate answers. The probability that the automatic answers are correct can be very high since the semantic patterns used can help avoid matching with those questions that are very similar in words and structures but not relevant in semantics. It is especially useful when the questions are not exactly the same. Once the patterns of the questions are matched, only the words in the place-holders are useful for further question matching. Figure 5 shows that our system can answer similar questions based on semantic patterns.

Our automatic answering method is described briefly as follows: We assume all the questions we have accumulated were asked previously by our users using semantic question patterns, which contain explicit structures and semantics. Hence, in our method, we exploit both structural matching and semantics matching between the new questions and the accumulated ones. Given a new question, we first obtain its main structure and key nouns and then find its patterns from the pattern database. These patterns are then filtered by the semantic labels of the key nouns of the new question to obtain the best matched pattern. The semantic labels of the key nouns are automatically found from the label list, which is mapped to WordNet. Finally, the most similar questions are found by evaluating the similarity between the key nouns of the new question and its counterparts in the accumulated questions previously asked with the matched pattern. The correct answers of those similar questions are retrieved as the answers for the new question.

4.3 User modeling

In the system, in order to achieve personalized information services as well as automatic answer assessment, we are particularly interested in the users' interests, authorities and

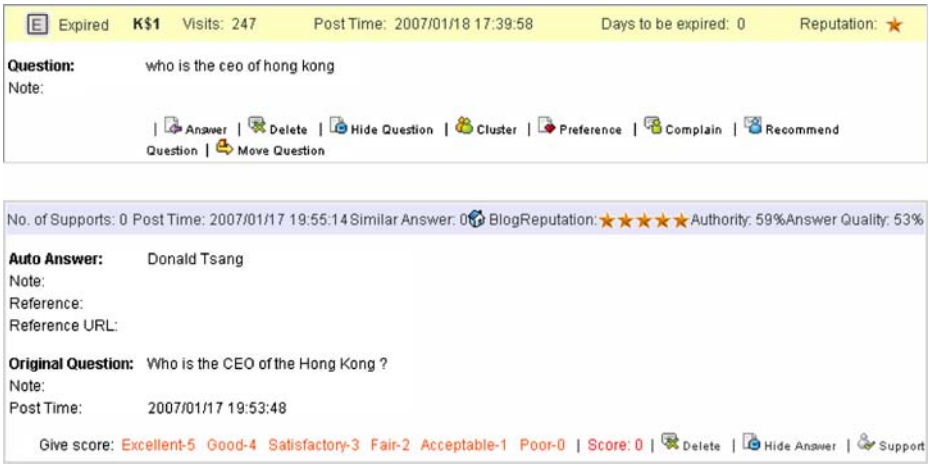

Figure 5 Automatic answering of repeated or similar questions.

reputations. Hence our proposed user model includes these three aspects. We first briefly define these three terms as follows:

- A user's interest is the topics (represented as boards/categories) of the questions and/or answers which he/she has most frequently read or accessed. Hence, it is often reflected by the number of questions in a particular board (i.e., category) he has ever read or accessed.
- A user's authority is a measure of his/her capability of correctly answering the questions on a particular topic (i.e., board/category). Hence, it is often reflected by the number of correct answers which he/she has provided and which have been adopted by the askers in the corresponding board.
- A user's reputation is a measure of his/her characteristics in the aspect of credibility, or in other words, the extent to which he/she can be trusted when he/she promises something.

The user models in all those three aspects are computed based on the records of the user's activities, including questioning, answering, supporting or selecting correct answers, and complaints. The interest and authority of a user in a specific board are simply calculated according to the above definitions. The reputation of a user is not board specific but valid for the whole system. It is more complicated as we discussed as follows.

Participants in online transactions are often at risks because they have little information about their partners. The difficulty of collecting evidence about unknown transaction partners makes it hard to distinguish between high and low quality service providers on the Internet [13]. The lack of this kind of information can be amended by trust and reputation. Therefore, a user reputation model is also proposed for the QA system. It does not only help to improve prospective users' trust and conviction in conducting online transactions, but also reduces the chances of fraud because typically traders are expected to maintain good reputation records in order to maximize their profits.

In *BuyAns*, the user reputation model is a combination of data from two sources, social network analysis and user rating. Social network analysis is based on an assumption of the importance of relationships among interacting units [14]. Because *BuyAns* is similar to an online virtual community compared with an online trade system, it is natural for us to use social network to analyze users' reputations.

In social network analysis, relational data is represented using graphs called *sociogram*, which is a directed and weighted graph [15]. Each participant is represented as a node and each relation is represented as an edge. The value of a node represents the importance of the node, which is an important factor that forms the corresponding user's reputation.

It is a common method to compute users' reputations by ratings among them in the reputation systems of current online trade systems. We adopt the idea of user rating and customize it to fit *BuyAns* since user rating is also an important evidence of users' reputations. More details on how to compute the reputation model in *BuyAns* are described in [10].

Similar to online trading, online user-interactive question answering may also be affected by the users' reputations. An asker's reputation will affect whether there will be answerers to provide answers to his/her questions. In addition, the reputation in *BuyAns* is also useful for answer quality assessment, as to be introduced in the next subsection.

4.4 Answer clustering and quality assessment

Traditional UI for QA or general forum systems simply displays all posts in a linear way, i.e., usually in an order of their post time. There are often many posts and many of them are very similar, however, a user still needs to spend quite some time to read through them. We develop a UI for answer clustering in *BuyAns*, which displays all answers in several clusters, each containing some answers similar to one other. Each cluster is represented by an answer either chosen or integrated from all the answers in the cluster based on their qualities, which are assessed according to their timeliness, their providers' authorities (capabilities) and reputations. The results are usually more concise after eliminating junk, redundant and inconsistent content in the answers. The proposed answer clustering and fusion UI is used to facilitate users' browsing and understanding of large sets of answers. It can also help the asker find more quickly and more accurately the correct answer(s) based on the answers' qualities as a hint. The same UI can also be used for other virtual communities, such as discussion groups, bulletin board systems, chat rooms, listservs, listprocs, and newsgroups.

By default, a user browses a list of answers with the normal view, in which the answers are simply sorted by their submission time. If the number of the answers submitted for a question is so large that he/she cannot quickly finish browsing them, he/she may choose the clustered view, which displays the answers in clusters sorted by their overall qualities (Figure 6). Each cluster is summarized by the number of answers it contains and an integrated answer based on the qualities of its answers and a chosen integration rule. A cluster can be expanded to show all the individual answers in it (Figure 7). More details on our answer clustering and fusion approach can be found in [7].

The quality of an answer is assessed based on its sources, e.g., the answerer's authority and reputation, the timeliness and references of the answer, and whether it is provided

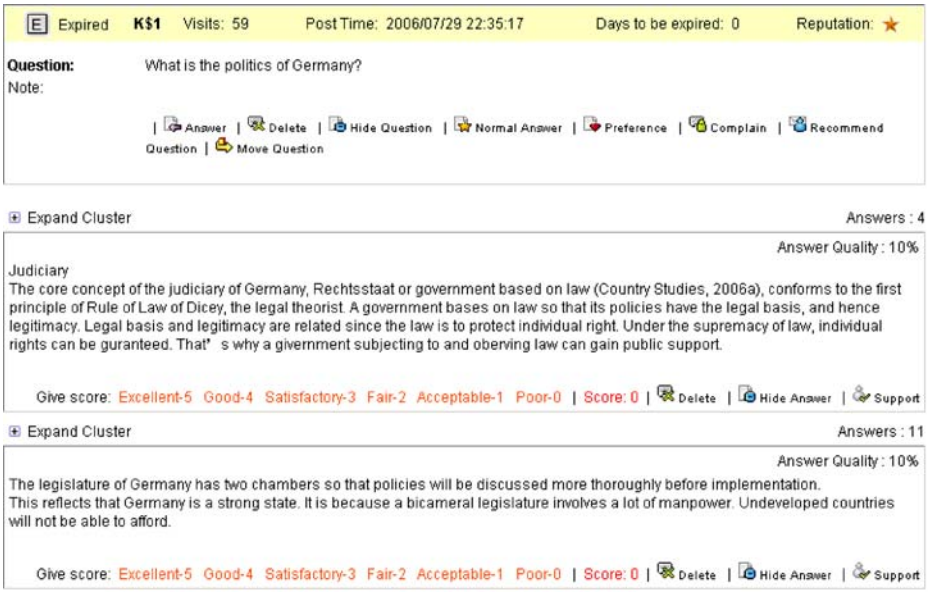

Figure 6 The answer page in the clustered view.

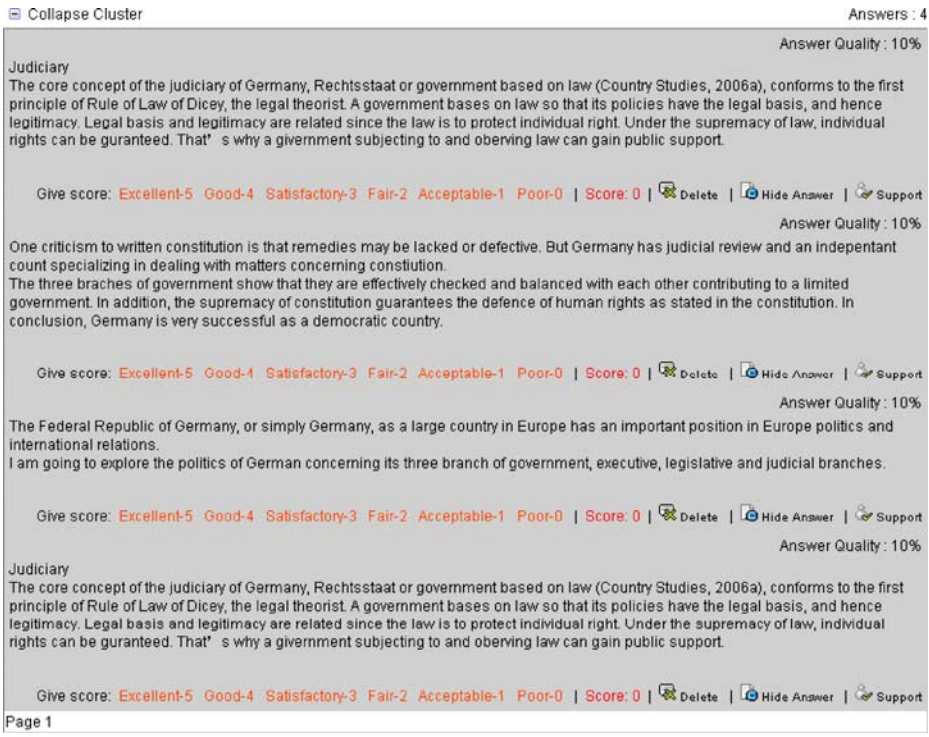

Figure 7 The answer page in the expanded view of a cluster.

automatically by the system. Usually, higher authority means higher probability of correct answers and higher reputation means more reliable ones. If an answer contains a reference (e.g., a URL), it has more chance to be a correct answer since the asker can verify its correctness very conveniently. A more timely answer also means more suitable while a correct answer provided 10 years ago may not be so reliable. More details on answer quality assessment can also be found in [7].

5 Application issues

BuyAns is a typical Web 2.0 application since it involves and relies on many users to help provide both questions and answers. In general, it can serve as a platform for knowledge acquisition for various applications which rely on efforts from many users. Especially, it can be used as a platform for technical support (or call-center) or employee continuous training for companies. Supported by certain business models, end-users of a company's product can be encouraged to help one another on the platform such that the workload of technical staff can be reduced dramatically and therefore the corresponding cost can be saved. New employees' questions related to their jobs can be answered by their senior colleagues and the internal knowledge of the company can be acquired and accumulated as a by-product. In this section, we briefly discuss potential business models which can be used for such platform and their applications, and present preliminary user studies.

5.1 Business models

Nowadays, the Web provides convenient marketplaces for all kinds of goods for all people all over the world. It should also be suitable for trading knowledge. People may only refer to knowledge of domain experts as knowledge or valuable knowledge. However, everybody knows something that may be useful to others. Ordinary people may think that their knowledge is not as valuable as experts'. This is due to lack of suitable knowledge trading system (or a marketplace for ordinary people's knowledge). However, their knowledge can be equally valuable if easily extracted, marketed, and then utilized, and therefore be a commercial product in the information era, especially with facilitation of the Web.

The *BuyAns* system can be considered as such a knowledge trading marketplace. Knowledge in terms of questions and answers requested by some users can be bought in this marketplace. The *BuyAns* system actually proposes and promotes a C2C business model for exchanging and commercializing knowledge from ordinary people.

The main business model of *BuyAns* is a reward scheme for answering questions. That is, a user can set a price when asking a question, say, K$1[8] (as shown in Figure 2), to indicate that he/she will pay the money for correct answer(s). Motivated by this offer, many other users will be willing to provide answers to the question. As we have mentioned in Section 3, the asker should select the earliest correct answer(s) from them as the final answer according to the rule, and the offered money will be paid to the provider(s) after deducting a corresponding commission fee for the system. Otherwise, potential complaint(s) or dispute(s) may be raised by other answer providers and should be settled by the system administrator with the help of a committee of experts in corresponding fields. Each complaint/dispute may cost extra money as well as reputation deduction from the loser, determined by the dispute settlement model and the reputation management model [10].

In addition to the main C2C business models for knowledge acquisition, more business models can be proposed and applied in *BuyAns* to encourage those activities that may help quickly accumulate knowledge in terms of both quantity and quality. In the user scenario we have mentioned in Section 3, the user whose previous answer is automatically selected for a new question by the system can still earn the money offered with the new question if the answer is selected by the asker as a final correct answer. The rule for selecting a final correct answer is that the asker should select the earliest correct answer(s), no matter whether it is automatically answered by the system based on previously accumulated knowledge or manually answered by users. This rule will encourage potential answerers to quickly provide their answers if they want to earn the money. Even though the money offered for a certain question is zero, potential answerers also have motivations to provide their answers since there are chances that their answers can be automatically reused to answer those new but similar (or even exactly the same) questions and they can still earn the money offered for the new questions. The earlier an answer is provided, the more chances it can be selected as a correct one. We also allow a user to answer his/her own questions. However, he/she should do so early so that his/her answers are the first ones that can be selected by himself/herself as the correct ones. Otherwise, other users may potentially provide correct answers before him/her and may cause disputes if they are not selected as the correct ones. In this sense, a hardworking user can quickly build a personal knowledge base that may cover a significant number of questions in a special knowledge area. The personal knowledge base contains all the correct answers selected for questions asked either by himself/herself or by others.

[8] K$ is the currency used in the system which is equivalent to HK$.

In order to encourage users to create useful patterns, each time a pattern is used (for questioning), its creator can also be rewarded in certain ways. Moreover, frequently used patterns are considered as high quality ones and those less used ones in a period of time are gradually dropped.

5.2 User studies

The *BuyAns* system has been used for more than 3 years during its development. We have been using it internally for group discussion and for discussions of several courses at the City University of Hong Kong. The first user study was done in April 2005, when the pattern-based QA UI was not ready. The system was originally designed for educational purposes and used to investigate the effects of knowledge sharing and acquisition. 87 students of the course CS3343 "Software Engineering Practice" at the City University of Hong Kong were asked to participate in a survey with 9 questions after 3 months of experience with the system. All the students were encouraged to actively participate in both asking and answering questions related to the course and its associated project. Each valid question earned one credit and each selected answer earned two credits. All the credits were finally contributed to their final marks of the course as extra bonus. Overall the system achieved a pretty good performance in terms of user satisfaction. Finally we collected 72 valid submissions and among them, overall 91% students had regarded the system as a good tool that could help their course studies. Especially, most of them would like to ask questions in the system if they had any, and actively answer others' questions if they could.

In April 2006, we did another user study on the pattern-based QA UI again with the CS3343 students as subjects. Most of the students did not have much experience on using this new UI. They were trained with brief training on how to use the UI before starting their tasks of asking 10 questions with various difficulties (from short and simple to long and complicated) using both the free-text UI and the pattern-based UI. After they finished the tasks, they were asked to answer 6 survey questions in the "e-Survey" board of *BuyAns*. The numbers of valid responses to these 6 questions were between 75 and 96. For the question of which UI was easier to use, 70% thought the free-text one was easier. This result was expected since several more clicks were necessary in the pattern-based UI. However, the rest 30% answers were also encouragement for us to continue with the pattern-based UI, which could definitely be improved a lot by better design. We were also happy with the answers of the question of which UI they liked more, among which only 39% disliked or strongly disliked the pattern-based UI and the rest 61% were "neutral" or "like". Compared with pattern-based UI, the business models received overwhelming acceptance. 80% of the answers to the question of how they liked the business models in *BuyAns* were "neutral", "like" or "strongly like". 74% would like to pay an amount of money between 1 to 100 HK dollars for an urgent question and 4% would like to pay even more. Even though most people felt that the pattern-based UI was more difficult to use, many would like to use the pattern-based UI if an amount of money (46% for 1–10 HK dollars and 12% for 11–100 HK dollars) could be saved, 36% would like to use the pattern-based UI even though no money could be saved, and only 6% would turn to use it if over 100 HK dollars could be saved.

The answers and statistics of the question of what factor could motivate a person to answer other people's questions on the Web could further validate our business model. From Table 1, we can see that 36% of people would be willing to answer those questions which wished to pay a small amount of money and 26% wished to answer for a significant amount of money.

Table 1. Answers of and statistics of the question: what factors (multiple choices) can motivate a person to answer other people's questions on the Web?

Answer (multiple)	Number	Percent
I usually volunteer to answer questions without pay	16	17
I sometime volunteer to answer questions without pay	23	25
I will be willing to answer those questions which wish to pay a small amount of money	33	36
I will be willing to answer those questions which wish to pay a significant amount of money	24	26
I will never answer questions on the Web no matter they are paid or not	9	9
I may volunteer to answer others' questions to show I am knowledgeable	18	19
Others	19	20
Total (91 subjects)	142	152

We have done a user study of the answer clustering and fusion UI [7]. We just briefly summarize its result and cite some numbers in this paper. We have compared our clustering/fusion-based UI with the traditional list-based one for browsing answers in terms of both the users' productivity to browse all the answers and their understanding effect of the answers. In the experiments, the subjects (40 CS research students or assistants in two groups, each using a different UI) were asked to first browse and read some threads of answers for some time and then do a 10-question comprehension test specially designed for each thread of answers. If the reading time was limited to 5 min, the users' comprehension of these answers using the clustering/fusion based UI was 33.3% higher than using the traditional list-based UI in average. If the reading time was not limited, the clustering/fusion based UI could save users' time by 22.3% to finish reading all the answers in a thread, and simultaneously, could also increase their comprehension of these answers by 26.3%. Furthermore, the comprehension per time unit was greatly increased by 62.3%, which means our new UI could significantly improve the efficiency of answer browsing.

In addition, the overall user-satisfaction we obtained on the answer fusion/integration result for each answer cluster was 73.9%.

6 Concluding remarks

We have proposed and developed a Web-based user-interactive QA system—*BuyAns* [1], where human users can offer money or get paid for good answers to important questions. Its system architecture, major functions and user interfaces have been presented in this paper. Preliminary user studies show the system is attractive to users' active participation due to the motivation by the business models. Its answer browsing user interface is also superior to the traditional user interface.

Given its attraction to active participation motivated by the business model and supported by the pattern-based QA functions and user interfaces, the system is expected to be used as a collaborative approach to knowledge acquisition. Knowledge acquisition is usually very expensive. It usually takes a lot of efforts of both knowledge engineers and domain experts to work together to extract and represent the domain knowledge. Especially, domain experts are very expensive. Actually, it is also the same expensive to extract and represent common knowledge in our daily life. However, the business model of the *BuyAns* system can stimulate and utilize all people's efforts to accumulate knowledge. Each user can serve as a domain expert in certain domain. With proper facilitation of the system,

knowledge extraction is just a natural, unpainful process. With the collective and collaborative efforts of all users, more and more knowledge will be gradually accumulated, represented, and stored in the knowledge base.

The pattern-based QA function and UI have been developed and encouraged for usage within the system, which are believed to be able to further facilitate knowledge acquisition and representation. The advantage of using pattern form for questions and answers is that patterns are more understandable for both machines and human beings, compared with natural language representation. Admittedly, the NLP capability of machines is still not mature for full understanding of our natural languages. The accumulated knowledge intermediately represented and stored in such pattern form can be converted with potentially the least effort to formal knowledge representation, which is efficient for machine understanding, processing, and reasoning. The ultimate goal is to provide automatic answers to repeated or similar questions by matching or reasoning, just like current search engines or automatic QA systems, but with more accurate results.

Due to the expected effectiveness of the collaborative approach to knowledge acquisition, we expect this system can be used in various domains, including employee training and technical support for end-users. In addition, we anticipate it as one of the hottest applications on the Web in the next wave, just like search engines in the current wave. Actually, it is a very typical Web 2.0 [2] application, which features, encourages, trusts, and relies on all users' participation to enrich its content (answers/knowledge) on the Web. The rich content can then benefit all the users in return for good reuse.

As a special kind of Web community, the *BuyAns* system reveals many features of a real-world society (community), in which each member can show his/her good reputation and capability/authority by contributing the high quality (correct and honest) content (answers) to the community. The entire community with *BuyAns* can also show its fairness, democracy, and other economic features of a real-world society by the business models and user management models. We also expect the system can be used as a platform for investigation of issues of social sciences, behavior sciences, economics, etc. Each member can virtually play a real role in such an economic society, just like in a real-world society.

However, there are also many potential problems we need to solve in order to let the system (and the business models) fully function to the best effect. From the business aspects, how to make fair rules and settle disputes that may arise is an important issue which may affect people's trust and willingness to use the system. We plan to establish a committee of experts, which can be either nominated or elected, for each board. Expert members can ask and answer like normal users. Normal users can also build their authority (capability) and reputations in the system through such activities and be elected to the expert committee. Since we plan to ask the users to use true names, especially when they want to transfer money out, how to balance privacy and credibility may also affect users' participation.

From the technical aspects, how to suitably design the Q/A patterns is a key problem we need to solve immediately. Certain theoretic issues, including reducibility, maximality, and completeness of patterns, should also be investigated. In addition, how to convert pattern-based Q/A pairs to knowledge representation is also a great challenge. We also hope this system can promote another wave of hot research of knowledge engineering or Artificial Intelligence (AI) in general.

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