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Information Presentation by Inferring User's Interests Based on Individual Conceptual Spaces

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SUMMARY

We present the system called *Takealook*, which personalizes information presentation according to the user's interests and knowledge. The system infers the user's interests from her/his question-and-answer interactions and the information presenters' conceptual spaces by using the related method of collaborative filtering. It then provides additional information about current contents and also recommends other related contents. The user's interests are represented by her/his own individual conceptual space (i.e., a set of related keywords) which is adapted to her/his preferences. In this paper we describe a method for personalizing the information presentation, implementating the system at reviewing an exhibition, and experimental results. © 2000 Scripta Technica, Syst Comp Jpn, 31(10): 41–55, 2000

Key words: Communication-Support System; personalized information presentation; user adaptation; conceptual space.

1. Introduction

We introduce an intelligent system called *Takealook* [12] which personalizes information presentation according to the user's interests and knowledge. This system assumes that a computer acts as a mediator between people since it is used for communication as distributing information. By analyzing the user's operation history and the conceptual information of the information presenters, the system infers the user's interests and knowledge so as to present the user with personalized information.

The user can employ the system to obtain basic knowledge which is used when the user communicates with someone. This may cause the user to become interested in information that she/he did not know or care about previously due to a lack of knowledge.

When we convey information to other people, we use various communication styles. In the case of synchronous conversation, we can change the details of the information according to the receiver's reaction. However, in the case of asynchronous communication, such as writing, the presentation of information tends to be one-sided. By using the computer as a medium for information distribution, information can be personalized according to each user's interests and knowledge. People are able to use various types of explanations when speaking. When speaking to a novice, people try to explain things simply and clearly rather than conscientiously, and try to avoid using technical terms, whereas when speaking to a specialist, people explain things in more detail, using more technical terms. In the same way, intelligence mediation by a computer can be used to present information according to each user's interests and knowledge.

The purpose of the Takealook system introduced in this paper is to distribute information according to interests and knowledge through asynchronous communication, similar to the way people communicate via a computer. Takealook focuses on that area of communication marked with diagonal lines in the figure. It facilitates asynchronous and personal communication by intelligence mediation.

This system can be used to facilitate communication between people from different fields and cultures. Specialized terminology can differ greatly according to specialty, occupation, life environment, interest, and so on. Understanding one another can occur when two people share basic knowledge about the subject of the conversation. In the case of communication between people who speak different languages, speech translation system [15] technology will allow them to understand each other. However, even if one becomes practical, it will still be difficult for speakers to understand each other if they do not have knowledge or experience related to the topic of the conversation. Takealook can be expected to be used to present the knowledge needed for communication and thereby human–computer interaction. As a result, human-to-human communication should facilitate communication and increase the curiosity of the users with regard to intelligent activity.

Knowledge and curiosity affect each other and change dynamically. For example, often when someone receives important information, she/he does not understand it and is not interested in it because she/he has no knowledge about it. In contrast if she/he does have knowledge about it, she/he is more likely to be interested in it. Likewise, if she/he has prior interest in it, she/he is more likely to want to learn more about it. Rather than stifling curiosity. Takealook presents information in such a way that encourages the user to explore information on her/his own initiative.

The basic idea of Takealook is to provide additional personalized information about the current contents. A related method of collaborative filtering is used to infer the user's interest from her/his question-answering history and the information presenters' conceptual spaces, which consist of keywords each of which has different degrees of relationships with the other keywords. By inferring the user's interests beforehand, the system can present detailed information and recommend other information that the user might be interested in.

In Section 2 we introduce the background and motivation of the research on Takealook, and in Section 3 we discuss related work. In Section 4 we introduce the framework and structure of Takealook. In Section 5 we describe an implementation of Takealook. In Section 6 we describe our experiment and evaluate the data we obtained. Finally, in Section 7 we describe the results of this research and future work.

2. Background and Motivation

This research was based on the assumption that the computer is a tool for intelligence-related activities, not that the computer program itself is intelligent [16]. That is, the computer is simply a support tool for human-to-human communication. Recently, the relationships between humans and computers have come to be classified in the following ways:

- Adaptation by users to computers, often referred to as a *user-friendly* relationship [8].
- Adaptation by computers through user customization, often referred to as an *adaptable* relationship.
- Adaptation from computers automatically, often referred to as an *adaptive* relationship.

In this research our aim was to achieve the third relationship—computers adapt to humans automatically.

Human curiosity is said to include both *diverse curiosity* and *specific curiosity* [6]. Diverse curiosity occurs due to boredom or a lack of information. In this case, searching covers a wide range of information. For example, when information is retrieved due to diverse curiosity, the user most likely wants to have a lot of information to choose from and to search for it manually. Specific curiosity involves specific and specialized information. In information retrieval due to specific curiosity, the user usually wants to obtain specific information as efficiently as possible.

Our specific objective was to develop a system that would enable a user's interests and knowledge through its interactions with the user and to present information automatically according to the user's interests. As a result, the system would promote the user's curiosity.

Applying human interests and knowledge to the field of engineering, we adopted two premises and constructed two hypotheses. One premise is that a person's interests and knowledge can be deduced from the questions she/he asks. In the field of cognitive science, observing questions is one way to determine human interests and knowledge, and questions are related to human interests and knowledge [5, 7]. In our research, we used this approach to determine the user's knowledge and interests, and as a result, our system does not impose a burden by the user.

Another premise is that individuals have different concepts consisting of various viewpoints. We use a conceptual space to represent these concepts. The conceptual space consists of some concepts, that is, viewpoints; they are constructed of keywords and represent keyword relations. The conceptual space thus depends on the person to whom it belongs, but some concepts are partially reusable. Similar ideas have been used by cognitive scientists and philosophers as a model of human concept formation process [4, 9].

Using these two premises, we constructed two hypotheses of inference and activation of human interests.

- Concepts related to the user's interests are inferred to be candidate interests in the presenters' conceptual spaces.
- Presenting information that the user is interested in arouses her/his interest.

We discuss the implementation of the model of human curiosity and concept based on these premises and hypotheses.

3. Related Work

The question answering system for know-how knowledge targets information distribution between the number of information presenters and the users. For example, Ref. 2 reports a method which uses a relationship network to be tuned by the user's question for supporting user's knowledge acquisition. It is known that if we prepare a meaning structure good results can be expected.

However, since this research uses many information presenters' information spaces, it will be very expensive to prepare many detailed meaning structures which cannot be easily modified. Since a meaning structure tends to be biased by the viewpoint of the person who puts the meaning in it, the system can consider a specific user's interests but cannot consider each user's interests individually. This can improve system performance for everyone, but not for individual users. Therefore, we proposed to use the structure of the information space as a simple related link that can also be used as a detailed meaning structure, in which the information presenter prepares conceptual space and the system prepares the user's interest space considering the individual's viewpoint and interests.

The information search or categorization within a wide information space, which has no meaning structure, has been previously studied, and is also related to this research. There are two approaches: One is processing robust natural language by simple keyword matching, and the other is modeling the user's interests in order to recommend and search for specific information. For the second approach, collaborative filtering [10] is often used for information recommendation by using a profile of a similar person.

It was reported that performance of information recommendation [1] is improved by combining the first approach, which indexes the presented information, and the second approach, which uses users' profiles [3]. This research uses these combined approaches by utilizing question–answer pairs, which provide the contents of the information, and the operational history of the user, which corresponds to the user's profile.

4. Framework

Figure 1 is the system framework proposed in this paper. There are information presenters in the upper part, user α in the lower part, and the system which is the mediator between these two in the middle. Many information presenters individually prepare the *information sources* and the *conceptual spaces*.

The information source consists of text information, keywords, and question–answer pairs. The text information is the basic information which everyone receives. The keywords are selected by each information presenter. The question–answer pairs correspond to keywords. The conceptual space consists of keywords which have mutual relationships between them according to their individual viewpoints.

The user finally receives *personalized information* and a *visualized interest space*. Personalized information means helpful assistant information corresponding to the user's interests which was presented from the system in advance when the user accessed the information. The information which the user received is the basic information and the assistant information.

In addition, recommendations for other information sources are provided. The interest space is the space that indicates user's interests. The visualized interest space provides a space to visualize the user's interests. The system presents information from the information presenters according to the user's interest space and operation records by using the *information retriever*.

On the whole, users search for information from databases of information presenters with their individual customized interfaces. When a user browses a certain information source, the system recommends appropriate information sources for further browsing, and presents detailed information based on the user's interests and knowledge, and then visualizes the user's interest space for visually navigating the information spaces.

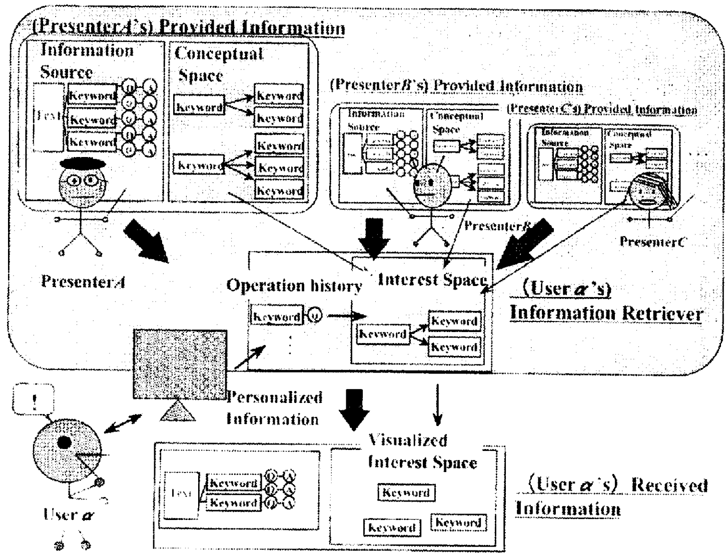

Fig. 1. System framework.

In the following subsections, we describe information preparation by information presenters, the mechanism for inferring user's interests, information recommendation, and the visualization of interest space.

4.1. Information preparation by presenters

The information prepared by individual presenters consists of *information sources*, which contain the information to be presented, and *conceptual spaces*, which consist of keywords which have mutual relationships between them according to their individual viewpoints.

The information source which consists of basic text information, keywords, and question–answer pairs is prepared by individual presenters. The information presenter determines beforehand which keywords and questions should be selected. For the information presenters selecting the questions, four kinds of questions are prepared: "*What (1)* is the meaning of this?" (dictionary-like meaning); "*What (2)* is the concrete meaning of this in this context?" (concrete meaning); "*How* is this achieved?" (methodology); and "*Why* do you use this methodology?" (reasoning of the methodology). These questions are designed based on the assumption that the content becomes more specialized based on the above order. Not all of the questions are always prepared with a keyword; it is also left to each information presenter to determine which question should be selected.

The conceptual space is a grouping of keywords defined by their relationships to each other. The presenters have the responsibility of preparing their individual conceptual spaces according to their own viewpoints. Each presenter uses words differently depending on his or her interests. Each keyword, which was selected by an information presenter in the process of preparing question and answering pairs, is linked to some keywords in the conceptual space by each information presenter. It is possible for a keyword to be linked to all other keywords in the system including the keywords of other contents.

There are different types of linkages, such as the inclusive relationships (Agent and Software Agent), the associative relationships (Communication and Interactive), and the similar relationships (Television and Radio). These relationships are defined as reversible relationships, and therefore the user's interest can be determined by any of the keywords. Each keyword linkage depends on intuition or the information presenter's viewpoint, so there are no strict guidelines.

4.2. Inferring user interests

The basic concept of inferring user's interests is based on (1) the user's question reflects her/his curiosity, (2) making full use of the user's operation records, and (3) developing the user's interest space, which is used for inferring interest, from several conceptual spaces of the information presenters. The system smoothly acquires the user's interests because it easily obtains her/his operation records through question answering by using it as personalized user's information.

The user's interests are inferred by information retriever using the user's individual interest space. When the user uses Takealook for the first time, the system structures the user's interest space by uniformly applying the conceptual spaces of all information presenters (Fig. 2).

Then, according to the user's accumulated operation records, the weights of the links between keywords in the user's interest space are changed. The user's interest space is generated automatically by using numbers of information presenters' conceptual space and by taking advantage of the user's selection of the questions. In this process, the keywords which the user questioned are regarded as the user's interests, and other related keywords in the user's interest space are regarded as candidates of the user's interests. In the interest space, between keyword relationships are indicated by weights from 0.0, which indicates no relationship, to 1.0, which indicates a strong relationship. The system searches keyword probability by using the weight values. The information retriever searches for a keyword with a high value which is related to the user's questioned keywords in order to determine the user's interests from the conceptual spaces. If there is a keyword that has been activated by previous questions, then the information retriever presents an answer to the keyword corresponding to the same kind of question that the user previously asked.

In this way, the information inferred to match the user's preferences is automatically shown as a suggestion by the system with the tracks of inferred keywords. The track of inferred keywords is not two keywords (e.g., *Keyword a* ↔ *Keyword b*) but three keywords (e.g., *Keyword a* ↔ *Keyword b* ↔ *Keyword c*).

Schneiderman said that it is important to show the reasons for automatic information presentation in the field of information retrieval research [11]. Therefore, our system shows the track of inferred keywords as the reason for automatically presenting information.

The automatically presented information is designed to help the user select information whether it is interesting or not. When the user selects the presented information as interesting or not, the weights of inferred keywords in the user's interest space are adjusted. Accordingly, interest space becomes personalized, and the system can adapt to the user interests step by step.

Thus, the system can infer the user's unknown interests from a wide conceptual space using comparatively little interaction. We provide an example of this process in the following.

(1) Extraction of keywords from the conceptual spaces to the interest space

In the case of Fig. 2, user α queried *Keyword b* of *How*. The keywords which are linked to *Keyword b* (e.g., *Keyword n, Keyword o, Keyword p, Keyword x, Keyword y*) are extracted from numbers of information presenters' conceptual spaces to the interest space (Fig. 3). Then, the links which do not exist in the interest space at that time are given an initial value of 0.5 (which is the middle value between 0.0 and 1.0). In the case of links which exist in the interest space, the weights they have at that time are used.

(2) Selection of presented information

The information retriever, which infers interests, selects a keyword from five candidates of keywords linked to *Keyword b*. The selection of a keyword from the candidates

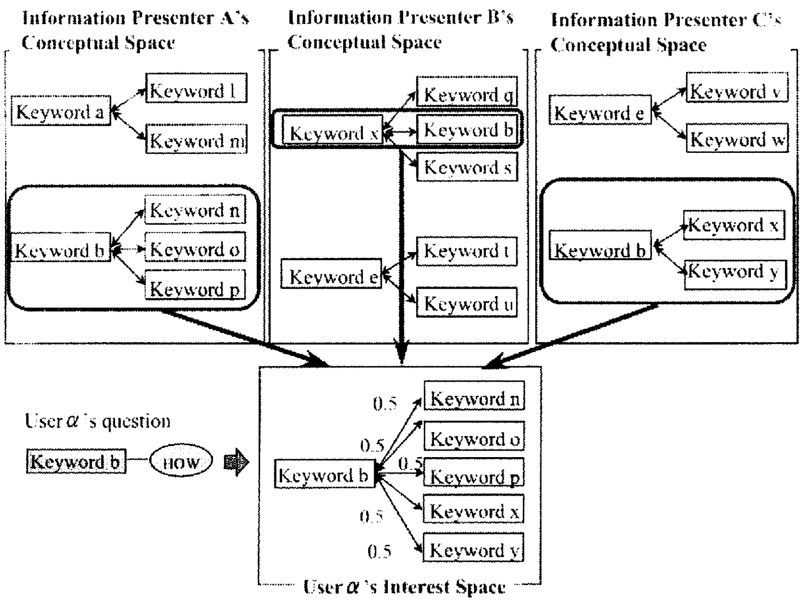

Fig. 2. Generation of interest space.

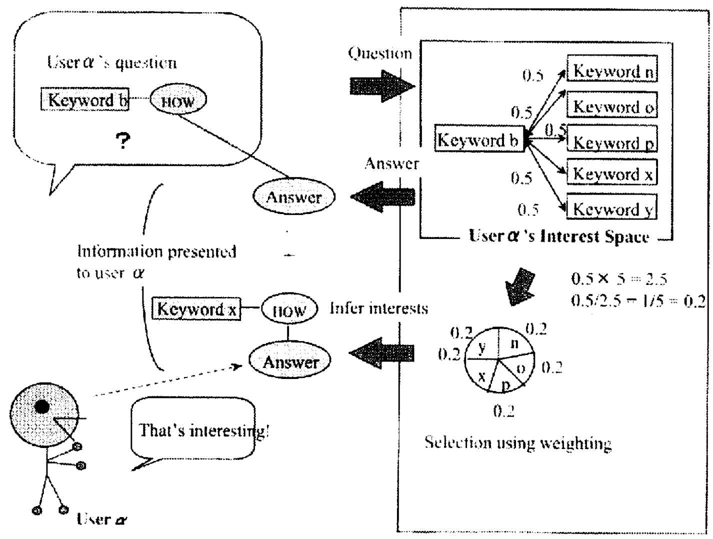

Fig. 3. Inferring interests by the information retriever.

is decided by probability according to the degree of the relationship. The system uses probability selection in which the denominator is the sum of the relationship degree of all candidate keywords and the numerator is the relationship degree of each keyword. The system allows searching for keyword links in two steps of inference (e.g., *Keyword a* ↔ *Keyword b* ↔ *Keyword c*). In this case, multiplication of each relationship degree found in this two-step inference is used to obtain the probability value for keyword selection. That is, if each of *Keyword a* ↔ *Keyword b* and *Keyword b* ↔ *Keyword c* has the relationship degree value 0.5, the value of links is $0.5 \times 0.5 = 0.25$. In this case, the value would be smaller than one-step inference, so that the keyword which was selected by using two-step inference would have low probability. When the probability selection was determined, *Keyword x* was selected in this case (Fig. 3). At that time, user α obtains the answer to *Keyword b* of *How*. At the same time, user α obtains the answer to *Keyword x* of *How*. If the answer to *Keyword x* of *How* doesn't exist, the next candidate is selected.

(3) Updating the interest space

The user indicates in the window of assistant information, which is presented automatically, whether it is interesting or not. If user α answers "*interesting*" to *Keyword x* of *How*, the system gives rewards to *Keyword b* ↔ *Keyword x*, which tracks inferred keywords. The values of rewards are set up to 0.1. As is often the case the value could be over 1.0, but in this case it is always set to 1.0. At the same time, the system searches for all information presenters' interest space. If a link in an interest space has the same keyword on either side of *Keyword b* ↔ *Keyword x*, a reward is given to the link in the interest space. In the case of Fig. 4, the interest space is updated by using the conceptual spaces of information presenters B and C, because these contain links for *Keyword b* ↔ *Keyword x*. At that time, the link (*Keyword b* ↔ *Keyword x*) itself is given a reward at first for updating the conceptual spaces. Because the links are reversible, *Keyword x* ↔ *Keyword b* is also given a reward. In the same way, if the link, which has the same keyword on the left-hand side of the rewarded link, is available, e.g., *Keyword b* ↔ *Keyword y*, *Keyword x* ↔ *Keyword q*, *Keyword x* ↔ *Keyword s*, it would also get a reward. However, if the user indicates that it is "*not interesting*," the weight of links would be lowered by the system. In the case of the track of inferred keyword which is two-step inference, the weight of each link is also adjusted.

This weight adjustment of keyword relations corresponds to a collection of several presenters' viewpoints which contains some parts that are more heavily weighted. By this repeated reinforcement learning, the user's interest space is refined.

4.3. Information recommendation

Information recommendation is decided by the recommended values which are calculated by each information source. Information recommendation is performed by showing a list of titles for each information source sorted by its recommended values.

Basically, the recommended values are decided based on whether the keywords and the questions that the user previously asked are included in the content, and whether

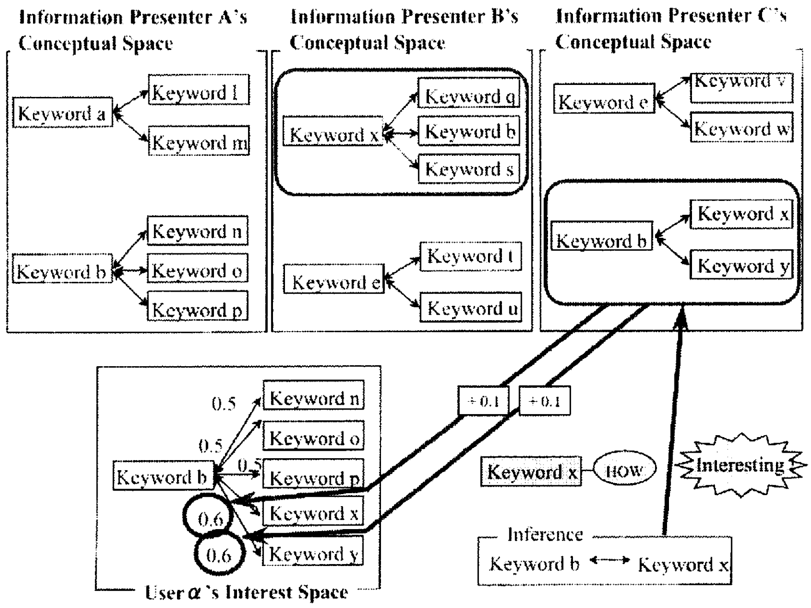

Fig. 4. Adaptation in the interest space.

the keywords and the questions associated with the user previously asked are included in the content.

The recommended value $R(I)$ is calculated as

$$R(I) = \sum_{i=1}^{n} \sum_{j=1}^{l} K_{ij} \cdot D_{ij}$$

i is the index of keywords found in the recent n operations of the user, j is the index of all keywords (the number of all is l) specified in abstract I, and K_{ij} is the factor corresponding to the keyword association (i.e., a relevant value between keywords i and j described in the user's conceptual space, which varies between 0 and 1). When these two keywords are the same, the value is 1. When these two keywords have no relevance, the value is 0. D_{ij} is a factor which indicates the existence of answer descriptions for keywords; it is determined according to the agreement between the kind of questions about keyword i (which the user has selected) and the kind of detailed information about keyword j in abstract I (which the presenter has prepared).

4.4. Visualizing interest spaces

User interest spaces are visualized and shown to the users in a two-dimensional space by matching the relationship of a pair of keywords to distance in the space by means of the multidimensional scaling method [14]. In this interest space, the keyword the user most recently asked is located at the center of the space, and the keywords related to it are located near it according to the relationship.

By viewing this visualized interest space, the user can understand why the answering window is automatically presented and review her/his search history. The interest space is also expected to make the user curious, because the interest space shows keywords and their relationships which may be unknown to the user.

5. Implementation

Takealook was intended for visitors to use to browse research areas they are interested in when visiting an annual open house of a laboratory [13]. Applying the framework shown in Fig. 1, the users are visitors, and the information presenters are the researchers in the laboratory. The information presenters provided a research abstract as an information source consisting of five- or six-line abstracts (text) of their projects, 5 to 10 keywords selected by them, and questions and answers (Q&As) corresponding to the keyword. There are 24 information sources, 175 keywords, and 3500 keyword links.

Figure 5 shows Takealook's user interface. The main window on the right consists of three parts: the list of titles of information sources sorted according to their recommended values (upper part), the text area showing the abstract of a selected information source (middle part), and the current visualized interest space of the user (lower part).

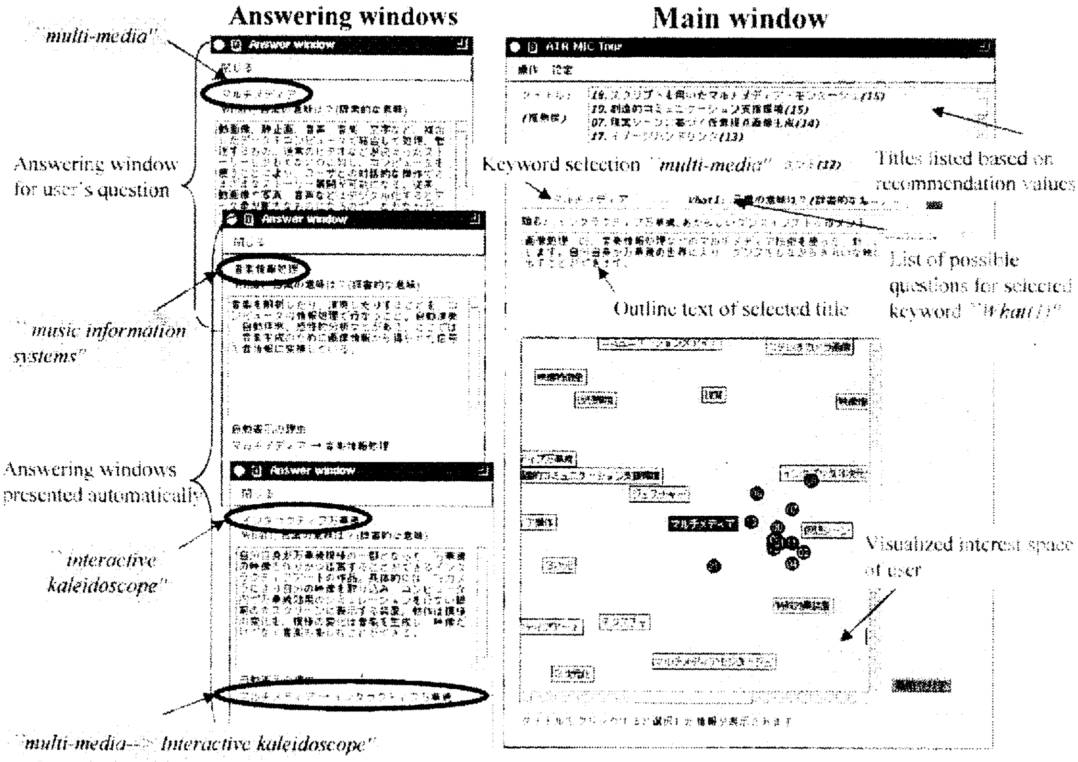

Fig. 5. User interface of Takealook.

By clicking a title on the list, the users can select interesting content. While viewing an abstract, the user can ask a question about a keyword by selecting a keyword and a question which were prepared. Then, the system shows the answer to the question with a pop-up window (answering window). At the same time, the system predictively presents other (one or two) answering windows about other keywords in the abstract, which are inferred to be relevant to the user's current interests. The system also displays the current interest space of the user showing relationships among keywords in her/his interest space. The keywords are represented by rectangular icons in the space. The round icons in the space indicate the information sources and are located in the center among the keywords extracted from the content. The user can select the contents by clicking these round icons in the same way as clicking on a title of the list.

We show an example of a user who is unfamiliar with computers. If the user asks the question “*What (1)* is the meaning of *multi-media?*” when reading an abstract of a certain research project by selecting keyword “*multi-media*” and question “*What (1)*,” the system responds by showing the answering window. At the same time, the system automatically shows the answer to the question “*What (1)*” of other keywords related to “*multi-media*” (two windows seen at lower left of Fig. 5). In this example, the system decides to show the “*What (1)*” meaning of “*music information systems*” and “*interactive kaleidoscope*,” because the “*music information processing*” and “*interactive kaleidoscope*” are associated with “*multi-media*” according to some of the presenter's conceptual spaces. These answering windows are expected to provide help to the user in acquiring knowledge and better understanding. In the answering windows presented automatically, traces of inference, which indicate the information has been presented, are shown at the bottom of the answering window (e.g., “*multi-media → interactive kaleidoscope*”).

Figure 6 is an example of this user selecting another content in the next browsing. In this example, because the user evaluated the “*What (1)*” information on the keyword “*music information processing*” as “*interesting*” in the last session, the system presents information about “*What (1)*” of “*music playing support*,” and “*improvised music playing support*.” Note that the interest space of the user in Fig. 6 is richer than that in Fig. 5.

We next consider an example of a user who is very familiar with computers. If the user asks the question “*What (1)* are the concrete types of *PDA*?” (Personal Digital Assistant) by selecting the keyword “*PDA*” and the question “*What (2)*,” then the system automatically presents the

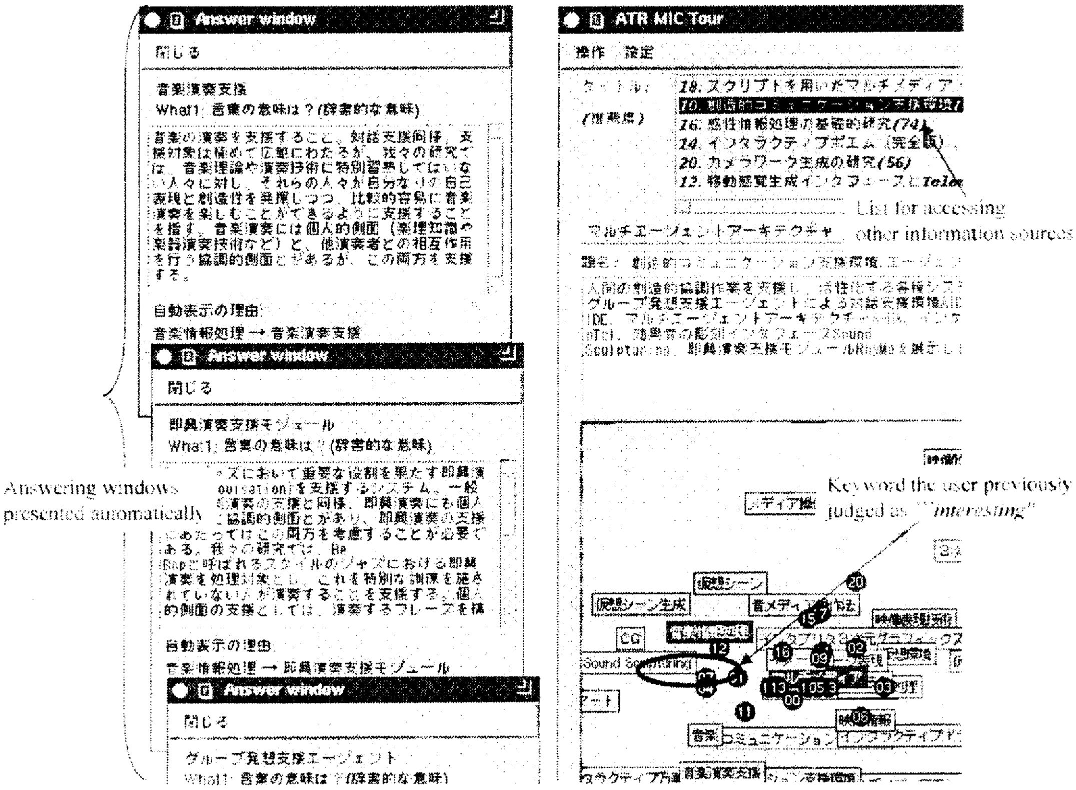

Fig. 6. Automatic presentation of answering windows for related keywords.

answer to "*What (1)*" are the concrete types of "*PC?*" (Personal Computer) when the user moved to another content that contains a question "*What (2)*" with each inferred keyword "*PC*."

This example shows that personalized information presentation encourages specific curiosity in users who have particular interests.

6. Experiment and Evaluation

In order to evaluate the proposed method, we performed an experiment with 38 subjects (university undergraduate and graduate students). Twenty-five of them majored in computer science and the others majored in fields such as material science and education. Before the experiment on system usage, we asked each subject if she/he were interested in the domain or keywords of the information content presented by the system (i.e., computer technologies on multimedia and communication science). The domain category we use is that of *Information Processing Society of Japan*, because it covers the domain of this content. All 175 keywords which come from Q&As of all of the information sources are used.

In the experiment, subjects are made to use the *Takealook mode* or *random mode* which she/he doesn't know. The Takealook mode is the normal mode in which the system presents information using adaptation of interest space. The random mode is a comparative mode in which the system presents information randomly in the information of content. The subjects first access information which she/he wants to see and continues until she/he is satisfied. The experiment is analyzed in three ways. We analyzed the operation history in order to quantitively evaluate the accuracy of information presentation. And we gave the subjects questionnaires before and after the system trial to obtain subjective evaluations. Then, by putting these results together, we evaluate an effect on the change in the user's interest due to interaction with the system.

6.1. Quantitative analysis of information presentation accuracy

In the experiment, we prepared two modes of information presentation: one is normal mode using the acquired interest space of the user, and the other presents information at random regardless of the user's interest space. We asked each subject to use this system in one of the two modes which she/he doesn't know, and let her/him start with any information source according to her/his interests and continue the browsing till she/he was satisfied.

We expected that the ratio of the number of answering windows which were judged "*interesting*" by the users would be higher than that of "*not interesting*." This should further increase accuracy of the automatic information presentation by the system's acquiring the user's interests. We confirmed this by obtaining the number of answering windows which were judged "*interesting*" and "*not interesting*" by the user from operations histories.

Figure 7 shows the results for a typical user, whom we call a *progress type* user.

The horizontal axis of the graph shows the accumulating number of answering windows, which include automatically presented windows as well as windows that answer particular questions. The vertical axis shows the ratio of the number of answering windows among all answering windows, including the answering window the user questioned.

This graph shows that the system excessively provided the user with *not interesting* information at the beginning but gradually provided more *interesting* information as the user's interest space progressively developed.

We blindly assigned 22 subjects in the experiment to the *Takealook mode*. The results from the 21 subjects could be regarded as *progress type*, that is, the amount of *interesting* information was at the end greater than that of the *not interesting* information. The remaining one subject was a so-called *all interesting person* (i.e., evaluated all of the provided information as *interesting*). The results show that this method succeeds in inferring the user's interests and is effective in selecting the appropriate information to be automatically provided to the user.

On the other hand, 7 of 16 subjects assigned to the *random mode* were regarded as the *no-effect type* (i.e., the amount of *interesting* information did not increase and at the end the amount of *not interesting* information was more than the amount of *interesting* information) (see Fig. 8).

However, we had seven *progress type* subjects as well. A common characteristic among the latter seven subjects was that all of them were computer science students and/or were interested in the provided domain of information according to the preliminary questionnaires. We consider that there were *progress type* users in *random mode*, because users committing to the domain would raise their own specific curiosity on their own and gradually increase understanding of the domain.

The remaining two subjects in the *random mode* were the *all interesting type* (see Fig. 9). None of the three *all interesting type* subjects, including the one subject mentioned above, were computer science students. We assumed that these three subjects could not focus the scopes of their interests and they did not have specific curiosity but had much diverse curiosity, so they evaluated all of the provided information as interesting.

6.2. Subjective analysis of user's trial

We distributed a questionnaire to the subjects before and after they used the system to obtain their impressions of this system. This questionnaire contains items on the function of the system (e.g., information presentation; information recommendation), the gadgets of the system,

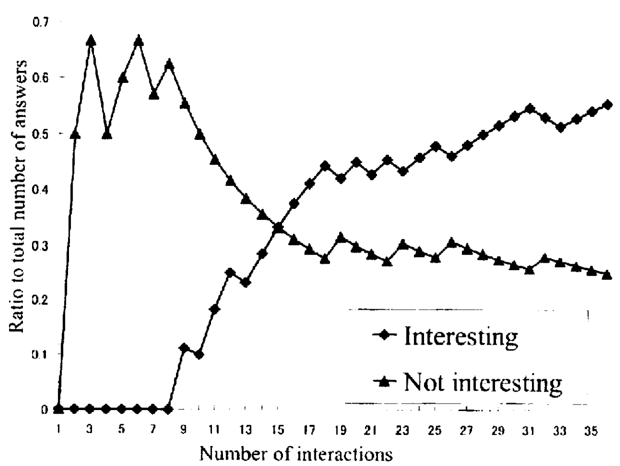

Fig. 7. Transition in evaluation of automatically provided information by a *progress type* user.

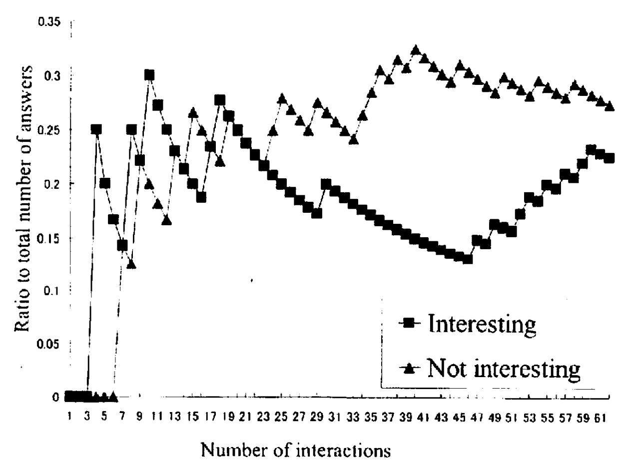

Fig. 8. Transition in evaluation of automatically provided information by a *no-effect type* user.

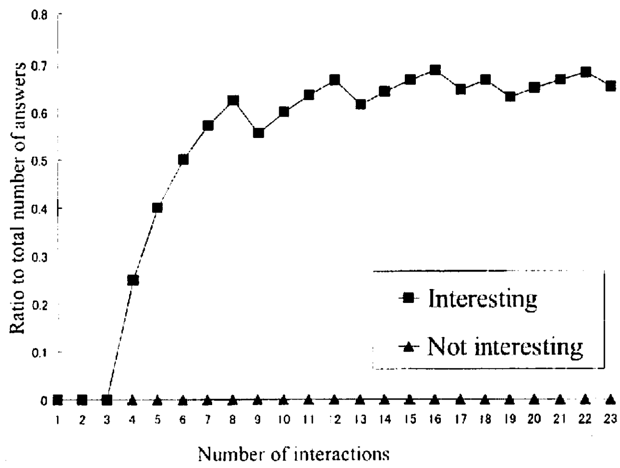

Fig. 9. Transition in evaluation of automatically provided information by an *all interesting type* user.

(e.g., answering window; interest space; question answering interaction), and the total impression to be answered.

The questionnaire expresses the user's impression in five stages. Most items in the questionnaire should be answered with the reason description by the user for the reliance of each answer. We assume the values of stage greater than three are affirmative. As a result, the following results are observed.

- **Efficiency of exploring information**

The majority of users found that the recommended value was effective. Then, many users search information using the recommended value. The users accessed 46% of the contents' index themselves, and 10% of the prepared information. However, 90% of the users answered that Takealook presented new and interesting information. That is, the users escaped from exploring all of the information from end to end by Takealook's recommendation.

Table 1. Change in interests of Takealook users

Interaction	Keyword Constant	Increase	Decrease
Interesting	3.95	3.76	1.67
Not interesting	1.19	1.57	0.76
Questioned	1.14	1.71	0.43
Nothing	8.90	5.67	8.14

Table 2. Change in interests of random mode users

Interaction	Keyword Constant	Increase	Decrease
Interesting	2.19	2.75	1.00
Not interesting	1.75	1.19	0.94
Questioned	6.13	6.56	2.00
Nothing	15.50	10.44	14.25

- **Accuracy of information presentation considering each user's dynamic interests**

The majority of users said that the recommended value was effective. Then, 90% of the users changed the categories of interest, and 95% of the users changed the keywords they take interest in. That is, Takealook presents new and interesting information according to the user's dynamic interests.

- **Curiosity activation**

These observations (90% of the users changed the categories of interest, and 95% of the users changed the keywords they take interest in) show that the user's interests change dynamically. Then, 90% of the users answered they were able to obtain information according to user interests, and 81% of the users found their curiosity was extended. That is, Takealook activates the user's curiosity.

6.3. Analysis of effects of the system on the change in the user's interest due to interaction with the system

We analyzed effects of the system on the change in the user's interest due to interaction using the user's operation histories and questionnaire and previous results. We define a word *constant* as the keyword answered "*interesting*" before and after the system trial in the questionnaire, a word *increase* as the keyword answered "*interesting*" only after the system trial, and a word *decrease* as the keyword answered "*interesting*" only before the system trial.

In operation histories, we define a word *interesting* as the keyword answered "*interesting*" when the answering window was opened automatically, a word *not interesting* as the keyword answered "*not interesting*" when the answering window was opened automatically, a word *questioned* as the keyword a user questioned on her/his own

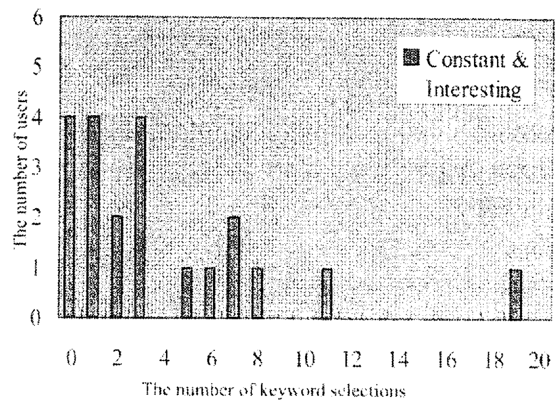

Fig. 10. Distribution of "*constant* and *interesting*" keywords for Takealook users.

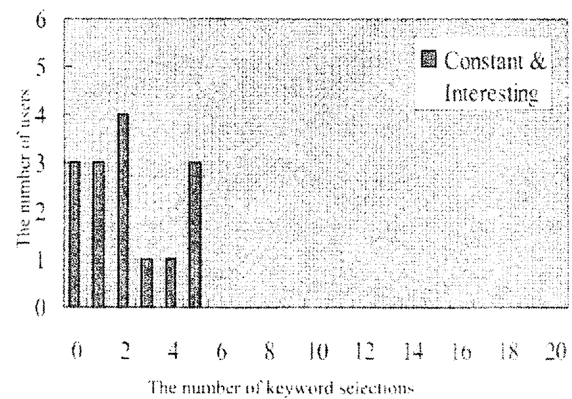

Fig. 12. Distribution of "*constant* and *interesting*" keywords for *random mode* users.

initiative, and a word *nothing* as the keyword when no interaction occurred during the user's operation.

Table 1 shows averaged changing interests of the Takelook users that we obtained by comparing the questionnaires and operation histories. Table 2 shows these changes for the *random mode* users.

Note the two values of "*constant* and *interesting*" and "*increase* and *interesting*" because the former shows accuracy of information presentation according to the user's existing interests ("*the value of information presentation accuracy*"), and the latter shows the effects on the user's unknown interests, that is, curiosity activation by the system ("*the value of curiosity activation*").

In Table 1, the values for information presentation accuracy and curiosity activation for the average Takealook user are 3.95 and 3.76.

Figures 10 and 11 show the Takealook users' distribution maps of the values of information presentation accuracy and curiosity activation which used firsthand data before averaging. Figures 12 and 13 show those of *random mode*. The horizontal axis is the number of keyword selections during operation and the vertical axis is the number of users.

Comparing these graphs, in either case of the value of *information presentation accuracy* or the value of *curiosity activation*, the *Takealook mode* has a higher value of these than does the *random mode*. It can be seen that some users have high values for the *Takealook mode* and no users have high values in the *random mode* in the user distribution maps.

Therefore, it can be concluded that the automatic information presentation was better at reflecting the users' known interests as well as activating unknown curiosity.

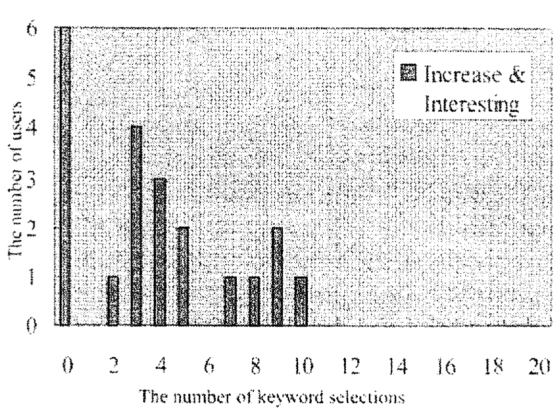

Fig. 11. Distribution of "*increase* and *interesting*" keywords for Takealook users.

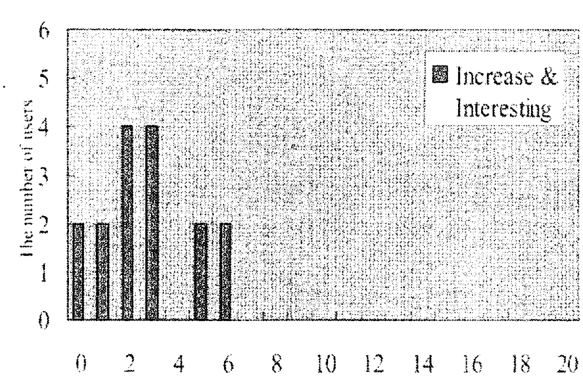

Fig. 13. Distribution of "*increase* and *interesting*" keywords for *random mode* users.

7. Conclusion

We proposed an information presentation method that adapts to the user's interests and knowledge. This is achieved by utilizing question–answer interactions, conceptual spaces, and a collaborative-filtering-related method. The implemented system enables users to find interesting information through comparatively little interaction, so that they have no need to explore the entire information contents.

Preliminary experiments revealed that Takealook is able to personalize information presentation so that it reflects the user's interests as a result of analyzing the user's operating histories and questionnaires. Questionnaires distributed before and after the system trials and the operation histories clearly indicated the system can flexibly adapt dynamically to the user's known and unknown interests.

In this system, we need to represent the provided information and individual user's interests. The abundant research conducted on knowledge representation so far has shown that complex and sophisticated structures of knowledge produce better results. In previous versions of this system, to raise the precision of inferring users' interests and providing information, we defined several other kinds of relationships between concepts (e.g., *is-a* and *part-of*), and prepared heuristic rules of association propagation according to these relationships. However, consistently managing such a complex knowledge structure takes much effort because we have to collect information sources from many presenters and a user's interests tend to change even during the short time she/he is using the system. Therefore, we now use a much simpler method that uses only associative relationships among keywords that are independently given by individual presenters and then tune the relational values according to the user's responses while using the system.

The number of answering windows automatically presented per question was previously a maximum of five in order to hasten the refinement of the user's interest space. However, it was too big a burden for users to evaluate all of the information as *interesting* or *not interesting*, so the results of the subjective evaluations were poor. Accordingly, we decreased the number of automatically provided windows to two, and this improved the subjective evaluations. Reducing the number did not slow down refinement of the user's interest space according to the experimental results.

One limitation of this method is that even if a user finds a new relationship between a pair of keywords, associative propagation between the pair would not occur unless at least one presenter has given a link between the pair. In cases such as this experiment, this issue would not be seriously revealed because the amount of knowledge of the presenters is clearly greater than that of the users. However, it would be beneficial if users could feed back new relationships among keywords so that presenters could be made aware of new and important viewpoints. Achieving such a mechanism is a future area of research. It would allow organic bidirectional communications between visitors and exhibitors beyond the current restrictions in exhibit-type knowledge conveyance and facilitate the emergence of dynamic ontologies among communities sharing common interests.

In the current version, we collected most of the information by hand, which took much effort. We need a more systematic mechanism for collecting information sources, one that leaves preparation of individual information sources to individual presenters. To achieve that, since *hypertext markup language* (HTML), for instance, is still too weak to embed semantic structures, we expect further improvement and popularization of document-tagging technologies that deal with semantic structures.

Future directions include reusing the acquired interest space of the user for further information exploration of different contents and for facilitating new encounters between users and information presenters based on their interest spaces.

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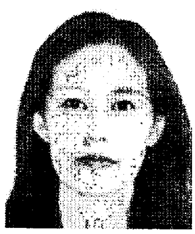

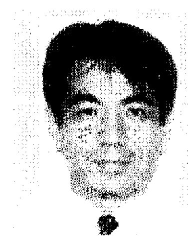

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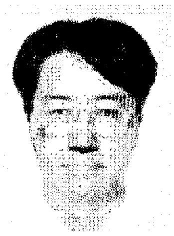

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