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A Face-to-face Education Support System Capable of Lecture Adaptation and Q&A Assistance Based on Probabilistic Inference

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***Abstract*—**Keys to high-quality face-to-face education are ensuring flexibility in the way lectures are given, and providing care and responsiveness to learners. This paper describes a face-to-face education support system that is designed to raise the satisfaction of learners and reduce the workload on instructors. This system consists of a lecture adaptation assistance part, which assists instructors in adapting teaching content and strategy, and a Q&A assistance part, which provides learners with answers to their questions. The core component of the former part is a "learning achievement map", which is composed of a Bayesian network (BN). From learners' performance in exercises on relevant past lectures, the lecture adaptation assistance part obtains information required to adapt appropriately the presentation of the next lecture. The core component of the Q&A assistance part is a case base, which accumulates cases consisting of questions expected from learners and answers to them. The Q&A assistance part is a case-based search system equipped with a search index which performs probabilistic inference. A prototype face-to-face education support system has been built, which is intended for the teaching of Java programming, and this approach was evaluated using this system. The expected degree of understanding of each learner for a future lecture was derived from his or her performance in exercises on past lectures, and this expected degree of understanding was used to select one of three adaptation levels. A model for determining the adaptation level most suitable for the individual learner has been identified. An experimental case base was built to examine the search performance of the Q&A assistance part, and it was found that the rate of successfully finding an appropriate case was 56%.

***Keywords*—**Bayesian network, face-to-face education, lecture adaptation, Q&A assistance.

I. Introduction

Although online education using the Internet and other ICT technologies is becoming prevalent, face-to-face education, in which an instructor teaches a number of learners in a class, is still the standard method of teaching in most educational institutions. In this method, the instructor aims to satisfy as many learners as possible in a class, which may consist of learners with different levels of understanding and proficiency. The instructor makes a variety of attempts to raise the satisfaction of learners, such as providing exercises after each lecture to raise learners' degree of understanding and making sure that questions asked by learners are answered adequately. Whether these attempts are effective or not depends on the qualification and experience of individual instructors. Therefore, learners' level of satisfaction often varies depending on the individual instructor, even for lectures on the same subject. Another problem is that the harder instructors try to prepare and evaluate exercises in a bid to raise learners' satisfaction, the greater the workload on them becomes.

Cashman et al. [1] proposed a method of enhancing learners' satisfaction in face-to-face education. In this method, the instructor uses a Web-based Q&A system, and learners are required to solve exercises before the next lecture. Responses from learners help the instructor understand the status and characteristics of learners' understanding and so adjust the way he or she conducts the next lecture. Although the introduction of such a system can raise learners' satisfaction, it increases the workload on the instructor in preparing exercises and analyzing the exercise results.

A recent study identifies four attributes of instructors that are helpful in online education: (i) knowledge, (ii) facilitation/stimulation, (iii) timely and helpful instructor feedback, and (iv) care and responsiveness to learners [2]. It finds that the fourth attribute is the most effective in raising the satisfaction of learners.

Attention is focused on the importance of adapting teaching methods to learners, and a strategy has been proposed for providing educational material in a manner which is flexible and so can suit the degree of understanding of learners [4],[5],[6]. This strategy uses a causal network (Bayesian network [3]). A project is under way that aims to help local communities by providing university education to them using a ubiquitous learning system. It has been found necessary to introduce a help desk function to enable a wide spectrum of citizens to use this system. Therefore, a help desk system for the ubiquitous learning system has been studied [7].

It has been found that keys to high-quality face-to-face education are ensuring flexibility in the choice of educational

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material and teaching strategy, and providing care and responsiveness to learners. This paper proposes a face-to-face education support method that is designed to raise the satisfaction of learners and to reduce the workload on instructors. It is assumed that the instructor receives feedback from learners after each face-to-face lecture, in the form of learners' answers to exercises, and questions about lectures and exercises.

This study encompasses the adaptation of lectures using learning achievement maps, and assistance provided by a Q&A approach based on case base searching.

The aim of lecture adaptation using learning achievement maps is to ensure flexibility in the choice of educational material and teaching strategy. Exercises are given to learners after each lecture. Each learner inputs his or her answers into his or her learning achievement map. This map is used to calculate the degree of understanding of individual learners regarding past lectures, to derive the "expected degree of understanding" for the coming lecture, and to provide the flexible adjustment of the way the coming lecture is conducted.

The aim of Q&A assistance based on case base searching is to provide care and responsiveness to learners. The Q&A assistance system interprets learners' questions expressed in natural language (Japanese), extracts keywords that characterize each question, and searches the case base using these keywords as search keys for optimal answers, and provides answers to learners in natural language.

The function described above is generally called a "help desk" function, and many studies have been made about this function [8],[9],[10]. As was mentioned above, a help desk system is currently being developed for a ubiquitous learning system that is intended to help local communities. The Q&A assistance method described in this paper has been developed based on the framework of this help desk system with customization for use in a face-to-face education support system.

Section II describes the concept of the face-to-face education system. Section II.A provides an overview of the face-to-face education support system, while section II.B describes lecture adaptation using learning achievement maps. Section II.C describes Q&A assistance based on case-base searching.

Section III describes the construction of a prototype face-to-face education support system, and evaluations made using this system.

II. Concept of the Face-to-Face Education Support System

A. Overview of the Face-to-Face Education Support System

Fig. 1 shows the overall organization of the face-to-face education support system. The system consists of the lecture adaptation assistance part and the Q&A assistance part. The former calculates the expected degree of understanding of the class for the next, forthcoming lecture from their answers to exercises that were given after each past lecture, and selects educational material and the teaching strategy for the next lecture accordingly. The learning achievement maps shown in Fig. 1 play a central role in implementing these functions. They use a Bayesian network (BN) [7] to calculate the expected degree of understanding of a learner for the next lecture from his or her performance on exercises given in previous classes. The class management map integrates the states of the learning achievement maps of different learners in the class and uses class adaptation knowledge to determine the teaching strategy for the next lecture. Class adaptation knowledge is a knowledge base that stores knowledge about what teaching content and teaching strategy are most appropriate for each lecture in light of the overall degree of understanding of all learners in the class.

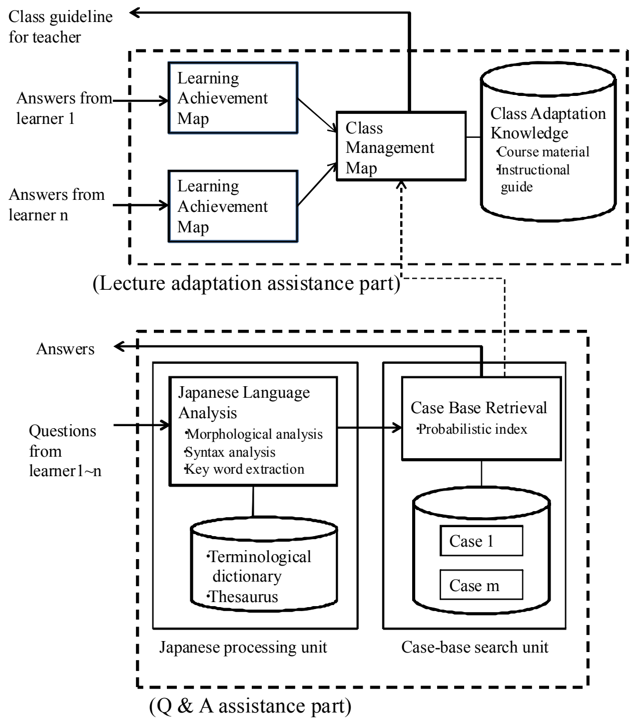


Fig. 1 Framework of the face-to-face education support system

The Q&A assistance part is a help desk for students attending the lectures and consists of a Japanese (language) processing unit and a case-base search unit. The Japanese processing unit receives questions from learners in natural language (Japanese) and extracts keywords that characterize each question. It consists of three functions: morphological analysis, syntax analysis, and keyword extraction. The case-base search unit searches the case base for the most appropriate case based on the keywords given by the Japanese processing unit, and sends the answer for the selected case to the questioner. The case base contains pairs comprising pre-defined questions that are considered likely to occur and matching answers.

B. Lecture Adaptation Assistance Method

This section focuses on the learning achievement map and describes its basic idea and the method of its implementation.

(1) Basic Idea and Method of Implementation of the Learning Achievement Map

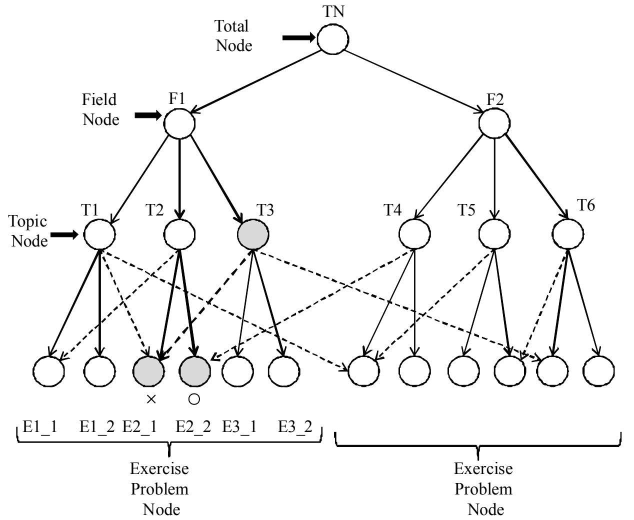


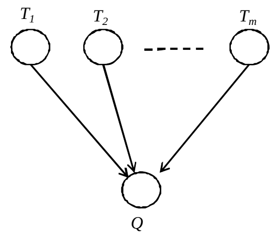
Fig.2 Structure of the Learning Achievement Map

As mentioned earlier, the learning achievement map is required to determine the degree of understanding of each learner for each lecture, and to provide a mechanism to ensure that learners' performance in exercises on past lectures is reflected in the way the next lecture is conducted. These are achieved using a Bayesian network, which is structured as shown in Fig. 2. The entire course of lectures is represented by the total node. A subject area within the course, here called a "learning field" is represented by a field node, while each topic discussed in a field is represented by a topic node. An exercise problem given for a topic is represented by an exercise problem node. Each of the nodes, the total node, field nodes and topic nodes, has two states: (the learner has) "understood" or "not understood". Each exercise problem node also has two states: (the answer by the learner was) "correct" or "incorrect".

Each link between two nodes indicates the existence of some relation between the two nodes concerned. An exercise problem node can have relations with not only the topic node it belongs to but also other topic nodes. The strength of each relation is represented by a conditional probability defined between the nodes concerned.

At the end of each lecture, learners must undertake an exercise that consists of a number of multiple-choice questions. In each multiple-choice question, the learner selects the one choice he or she thinks is correct from among a number of choices given. Learners must input their answers by one day before the day of the next lecture. It is determined automatically whether the input answers are correct or not, and this data is input to the exercise problem nodes shown in Fig. 2. When the states of all exercise problem nodes in the BN concerned have been determined, a certain probability propagation algorithm [3] is applied to update the probability of each state of each higher-level node successively. This probability not only indicates the degree of understanding of the topic already taught (the probability of the learner concerned having understood the topic) but also provides the expected degree of understanding of the future topics.

A distinctive feature of this approach is that these expected values are reflected in the way future lectures are conducted. For example, assume that Topic T2 has been taught and Exercise problems E2_1 and E2_2 have been given. Further assume that the learner in question has answered E2_1 incorrectly and E2_2 correctly. These results are reflected not only in T2 but also in T3, and consequently the expected degree of understanding for T3 is reduced. In other words, the impact of the correct answer for E2_2 is weakly reflected in T3 through the path of T2→F1→T3 (hierarchical path). The impact of the incorrect answer for E2_1 is not only weakly reflected in T3 through the same path but also strongly reflected in T3 through the cross path of E2_1→T3. As a result, the expected degree of understanding for T3 is decreased, and this fact is used as a pointer in determining how to conduct the lecture on T3.



$$P(Q=y\mid T_1,T_2,\ldots,T_m)=1-b\prod_{j\in Y}a_j$$

where, 'Y' represents a set of suffix r of node T_r with a link to Q and state 'y.'. 'y' and 'n' stand for *yes* and *no*, respectively. a_j and b (background noise) are defined as:

$$a_j = P(Q=n\mid T_j=y)$$
$$b = P(Q=n\mid T_1=T_2=\cdots=T_m=n)$$

Fig. 3 Noisy-or rule

(2) Use of the Noisy-or Rule for Setting the Conditional Probabilities in a Learning Achievement Map

As shown in Fig. 2, one exercise problem node may have links to more than one topic node. Suppose Exercise Problem Node Q has links to topic nodes T1 to Tm. Then, the conditional probability that should be set between Q and the topic nodes is expressed as P(Q | T1,…,Tm). The number of combinations of conditional probabilities to be set increases at a rate proportional to 2 to the power of m. If m is greater than 2, it is generally extremely difficult to determine conditional probabilities if all relations between topics are to be taken into consideration. It has been decided to use the Noisy-or rule [3] to simplify the calculation of conditional probabilities.

The basic idea of using the Noisy-or rule for the calculation of a conditional probability is shown in Fig. 3. When this rule is used, the calculation of P(Q | T1,…,Tm) is reduced to the calculation of the product of P(Q | Tj) (j=1,…,m), which are conditional probabilities between Exercise Problem Node Q and individual topic nodes Tj (j=1,…,m). In other words, the designer of a learning achievement map needs only to give the conditional probabilities between the exercise problem node concerned and each of the topic nodes that have links to this exercise problem node. Thus, the setting of conditional probabilities is dramatically simplified.

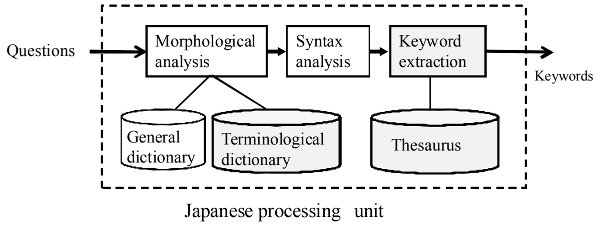


Fig. 4 Organization of the Japanese processing unit

TABLE I
EXAMPLE OF THE THESAURUS

ID	Thesaurus name	Keywords
1	Method	method, operation, handling
2	Variable	variable, field, attribute
3	Subclass	subclass, child-class, extend-class
4	Superclass	superclass, parent-class
5	Exception	exception, error, abnormal-event

C. *Q&A Assistance Method*

The Q&A assistance part is based on the framework of the help desk system for the ubiquitous learning system being developed, and has been customized to support face-to-face education. The basic ideas for its main components, the Japanese processing unit and the case-base search unit, are described below.

1. Japanese Processing Functions

The organization of the Japanese processing unit is shown in Fig. 4. In the help desk system [7], Chasen [8] was used for morphological analysis, and Kabocha [9] for syntax analysis. The keyword extraction part, the terminological dictionary, and the thesaurus were developed by the authors. Among these, the terminological dictionary and the thesaurus are dependent on the specific subject area in which the help desk system is used because they are used to extract keywords that are specific to the subject area concerned. So, these have been developed as new elements for subject area to face-to-face education. The thesaurus contains identifiers each of which is associated with a group of similar keywords. Some examples of the thesaurus are shown in TABLE Ⅰ.

2. Case-Base Search Using a Probabilistic Index

The organization of the case-base search unit is shown in Fig. 5. The keywords extracted by the Japanese processing unit from the question input by a learner are input to the case-base search unit. The unit searches the case base for the case that is most relevant to these keywords, and sends the solutions contained in this case to the questioner. As shown in Fig. 5, each case consists of a question part and a matching answer part. The question part contains keywords that characterize the question, and the answer part describes the answer for the question. An example of a case is shown in Fig. 6.

The first feature of the case-base search unit is the use of the index part shown in Fig. 5. The index part is built as a Bayesian network (BN) based on the case base. Specifically, a keyword node is associated with a keyword, and a case node with a case. There are links between a keyword node and related case nodes.

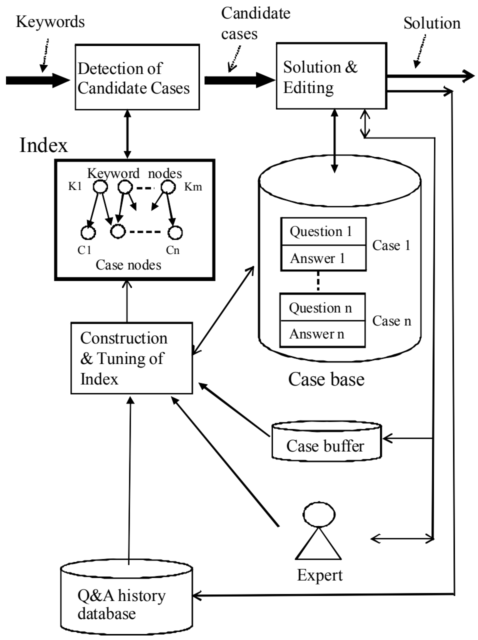


Fig. 5 Organization of the Case-base search unit

Question i
static variable, static field, variable, field
Answer i

･A variable belonging to a class
･It is shared with objects generated from the class
･Example of the description
class A {
static variable staticA;
}

Fig. 6 Example of a case

A case node consists only of the case identifier and a link to the actual case entity in the case base. Each Case node Ci is given a conditional probability P(Ci | Ki1, Ki2,…,Kin), which reflects the strength of the relation with each of the keyword nodes (Ki1,…,Kin) to which the case node has links. The Noisy-or rule described in Section II.C.2 is used to simplify the setting of these conditional probabilities.

The second feature of the case-base search unit is the ability to fine-tune conditional probabilities P(Ci | Kip) between a keyword and related case nodes using the Q&A history data that have been accumulated through the operation of the system. The Q&A history database in Fig. 5 stores the accumulated

Q&As. The construction & tuning of index part fine-tunes index parameters using the Q&A history database and the case buffer. The case buffer temporarily stores cases created by experts when the case base contains no cases relevant to the question asked.

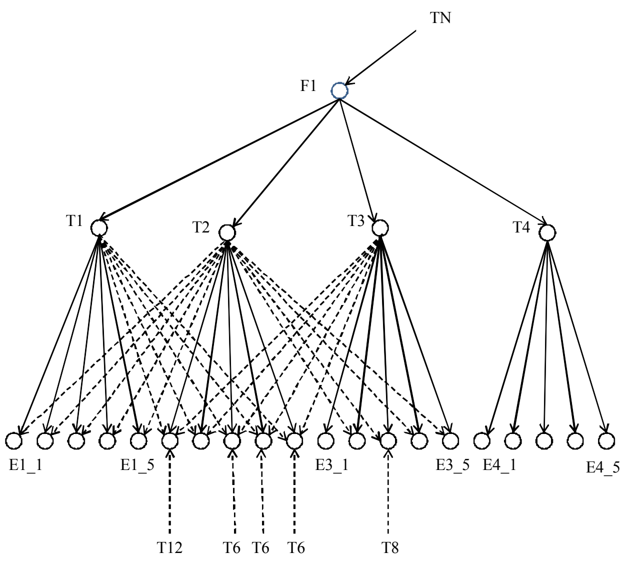


Fig. 7 Part of the experimental Learning Achievement Map

The part of the case-base search unit that depends on the subject area is data in the case base. Therefore, the case base has been developed as a new element for face-to-face education of a specific subject area. The index part has also been newly developed from the case base.

III. Construction and Evaluation of a Prototype Face-to-Face Education Support System

The educational support method was applied to the Java programming course in the authors' university. A prototype system that implements the lecture adaptation and Q&A assistance methods described in Section II was built, and these methods were evaluated. The prototype system and evaluation results are described below.

A. Prototyping of Lecture Adaptation and Evaluation

(1) Specific Method of Lecture Adaptation

The level of lecture adaptation for the next lecture was classified into three levels according to the expected degree of understanding of the class. The three levels are referred to as the higher, normal and lower levels. A different set of learning content and teaching strategy was prepared for each level.

Teaching strategy specifically means the way in which the next lecture incorporates the content of related past lectures.

(2) Organization of the Learning Achievement Map and Parameter Values

The Java programming course involved one lecture each week for 15 weeks. The content of the course was divided into six fields (subject areas) and 15 topics. Five multiple-choice exercise problems were developed for each topic. Each exercise problem had not only a link to the topic it belongs to but also links to other related topics. A part of the experimentally developed learning achievement map, relating to T1 to T4, is shown in Fig. 7.

TABLE II
SETTING OF CONDITIONAL PROBABILITIES

Category	Targeted position		Conditional probabilities
Hierarchical path	TN		P (TN = y) = 0.5
	TN - Fi		P (Fi = y | TN = y) = 0.65
			P (Fi = y | TN = n) = 0.35
	Fi - Tij		P (Tij = y | Fi = y) = 0.65
			P (Tij = y | Fi = y) = 0.35
	Tij - Eijk	d.o.d. = 1	P (Eijk = y | Tij = y) = 0.75
			P(Eijk = y | Tij = n) = 0.30
		d.o.d. = 2	P (Eijk = y | Tij = y) = 0.70
			P (Eijk = y | Tij = n) = 0.25
		d.o.d. = 3	P (Eijk = y | Tij = y) = 0.65
			P (Eijk = y | Tij = n) = 0.20
		d.o.d. = 4	P (Eijk = y | Tij = y) = 0.60
			P (Eijk = y | Tij = n) = 0.15
		d.o.d. = 5	P (Eijk = y | Tij = y) = 0.55
			P (Eijk = y | Tij = n) = 0.10
Cross path	Tpq - Eijk	d.o.i. = 1	P (Eijk = y | Tpq = y) = P (Eijk = y | Tij = y) / 3.0
		d.o.i. = 2	P (Eijk = y | Tpq = y) = P (Eijk = y | Tij = y) / 2.0
		d.o.i. = 3	P (Eijk = y | Tpq = y) = P (Eijk = y | Tij = y) / 1.5

The parameter values (conditional probabilities) in each learning achievement map were set as shown in TABLE II. The degree of difficulty of exercise problems was classified into five degrees: (1) easy, (2) rather easy, (3) normal, (4) rather difficult, and (5) difficult. A parameter value appropriate for the specific degree of difficulty was assigned to each link between an exercise problem and the topic it belongs to. Each link between an exercise problem and a topic other than the one it belongs to was classified according to how strongly the problem and the topic are related to each other. Specifically, such cross links were classified into three degrees of influence (d.o.i), and a different parameter value was assigned for each degree of influence. In the order of the degree of influence, the parameter value set to a cross link is the parameter value of the hierarchical path divided by 3, 2 or 1.5.

(3) Study of Lecture Adaptation Using Three Levels

Under the assumptions described in *(1)* and *(2)*, models which might be useful for determining the lecture adaptation level most appropriate for the obtained expected degree of understanding were studied, in order to adapt the next lecture according to the performance of the learners in the class in past lectures. These models are referred to as lecture adaptation discrimination models. Specifically the five candidate models shown in TABLE III were developed based on a theoretical study of the Java programming course conducted from April to

TABLE Ⅲ
LECTURE ADAPTATION DISCRIMINATION MODELS FOR THREE LEVEL ADAPTATIONS

Models	Range of expected d.o.u. for three level discrimination		
	Lower level (level 1)	Normal level (level 2)	Higher level (level 3)
M1	0.0 – 0.30	0.30 – 0.70	0.70 – 1.0
M2	0.0 – 0.35	0.35 – 0.65	0.65 – 1.0
M3	0.0 – 0.40	0.40 – 0.60	0.60 – 1.0
M4	0.0 – 0.45	0.45 – 0.55	0.55 – 1.0
M5	0.0 – 0.48	0.48 – 0.53	0.53 – 1.0

d.o.u : degree of understanding

TABLE Ⅳ
RESULTS OF THE EVALUATION OF THE FIVE LECTURE ADAPTATION DISCRIMINATION MODELS

Lecture number	Weighed average accuracy rate of the related past exercise problems	Expected value of d.o.u.	Results of level discrimination by each model				
			M1	M2	M3	M4	M5
2	0.82	0.64	2	2	3	3	3
3	0.88	0.60	2	2	3	3	3
6	0.79	0.63	2	2	3	3	3
8	0.57	0.47	2	2	2	2	1
9	0.78	0.49	2	2	2	2	2
10	0.80	0.54	2	2	2	2	3
11	0.75	0.50	2	2	2	2	2
12	0.64	0.50	2	2	2	2	2

July, 2008. Each model uses different ranges of the expected degree of understanding for the classification into the three adaptation levels. These models were compared in terms of how appropriately they select the lecture adaptation level for the next lecture based on the performance of the class in related past lectures. The evaluation results are shown in TABLE Ⅳ.

Each row in TABLE Ⅳ shows, for a specific lecture, the average rate of learners' correctly answering exercise problems for related past lectures taking the d.o.d. and the d.o.i. of each exercise problem into consideration. It also shows the expected degree of understanding for the lecture, and the lecture adaptation level assigned by each discrimination model. It was found that Models 3 and 4 in TABLE Ⅲ assigned levels in a way that does not contradict the level-assignment judgment by human experts. Therefore, the optimal discrimination model will be somewhere between Models 3 and 4.

B. Prototyping of Q&A Assistance and Subsequent Evaluation

(1) Building of the Case Base, Terminological Dictionary and Thesaurus

As described in Section II.C., it is necessary to build the case base, terminological dictionary and thesaurus specifically for the lecture course to which the system is to be applied.

TABLE Ⅴ
RESULTS OF THE EXPERIMENT ON RETRIEVAL RATE

	Java Programming (%)	U-learning System KUSEL(%)	Dialog Navigator (%)
Successful retrieval rate	56	77	58 (65)*
Unsuccessful retrieval rate with appropriate cases	16	5	8 (7)*
Unsuccessful retrieval rate without appropriate cases	28	18	34 (28)*

* with use of the method for improving inappropriate questions

A case base for the Java programming course was built by referring to textbooks, Webpages and literature. The case base contains 168 cases, each of which consists of a question part and an answer part as shown in Fig. 6.

A terminological dictionary and thesaurus for the subject area of Java programming were created. These are implemented into the Japanese processing unit shown in Fig. 4. No prior knowledge was available about the frequency at which each case is accessed by learners. So, in setting the parameter values (conditional probabilities for links between keyword nodes and case nodes) in the case search index shown in Fig. 5, it was assumed that, when a keyword is related to more than one case, it is related to each case equally.

(2) Evaluations of Search Performance

The subjects for an evaluation experiment were five students who had taken the Java programming course in the past and who did not know about the content of the case base. Each subject thought of 10 questions, and the successful retrieval rate for these questions were examined. Successful and unsuccessful retrievals are defined as follows:

Successful retrieval: There is an appropriate case in the case base, and it is among the top three candidate cases retrieved.

Unsuccessful retrieval (an appropriate case exists): There is an appropriate case in the case base, but it is not among the top three candidate cases retrieved.

Unsuccessful retrieval (no appropriate case exists): There is no appropriate case in the case base.

The results of this experiment are shown in TABLE Ⅴ. For comparison, TABLE Ⅴ also includes the successful retrieval rate for two systems in different categories: a ubiquitous learning system called KUSEL, which uses the same Q&A assistance framework, and the Dialog Navigator [11], which takes an approach similar to the study in this paper and which accepts questions in natural language (Japanese).

The successful retrieval rate for Java programming was 56%.

The authors will try to enhance the successful retrieval rate by reinforcing the case base for Java programming and also by fine-tuning the parameter values in the case search index.

IV. Conclusion

Considering that keys to high-quality face-to-face education are ensuring flexibility in the way lectures are given (in particular, educational material and teaching strategy), and providing care and responsiveness to learners, this paper has proposed a face-to-face education support system that is designed to raise the satisfaction of learners and reduce the workload on instructors. This system consists of a lecture adaptation assistance part, which assists instructors in adapting teaching content and strategy, and a Q&A assistance part, which provides learners with answers to their questions.

The core component of the former part is a learning achievement map, which is composed of a Bayesian network (BN). From learners' performance in exercises on related past lectures, the lecture adaptation assistance part obtains information that is then used to adapt the way that future lectures are conducted.

The core component of the Q&A assistance part is a case base, which accumulates cases consisting of questions expected from learners and corresponding answers to those questions. The Q&A assistance part is a case-based search system equipped with a case search index, which performs probabilistic inference.

A prototype face-to-face education support system has been built, which is intended for use in the teaching of Java programming in the authors' university, and this approach was evaluated using this system. For the lecture adaptation assistance part, how to associate the expected degree of understanding for the next lecture, which is derived from the results of exercises on the related past lectures, with one of the three lecture adaptation levels has been studied, and a model has been identified that indicates an appropriate range of the expected degree of understanding for each level. For the Q&A assistance part, a case-base search system with 168 cases has been built in the case base. An experiment was conducted with five subjects, each of whom thought of 10 questions. The successful retrieval rate obtained in this experiment was 56%. The successful retrieval rate is defined as the rate at which an appropriate case is found among the top three candidate cases retrieved.

The authors will try to enhance the successful retrieval rate by reinforcing the case base and also by fine-tuning the parameter values in the case search index based on their experience with the operation of the system.

References

[1] E. M. Cashman and E. A. Eschenbach, Active Learning with Web Technology-Just In Time!, 33rd ASEE / IEEE Frontiers in Education Conference, Boulder, U.S.A., pp.T3F-9-T3F-13, 2003.

[2] S. Eom, The Role of the Instructors as a Determination of Students' Satisfaction in University Online Education, Proceedings of the Sixth International Conference on Advanced Learning Technologies, Kerkrade, Netherlands, pp.985-988, 2006.

[3] F. V. Jensen, Bayesian Networks and Decision Graphs, Springer-Verlag, 2001.

[4] Y. Fujiwara, Y. Ohnishi, H. Yoshida, A Method for Tuning the Structure of a Hierarchical Causal Network Used to Evaluate a Learner's Profile, IEICE Trans. Inf. & Syst., Vol.E89-D, No.7, pp.2310-2314, 2006.

[5] Y. Fujiwara, H. Yoshida, Y. Maeda, S. Okada, T. Suzuki, Ubiquitous Learning System Featuring User-adaptive Teaching Strategy, Proceedings of the IADIS International Conference CELDA 2006, Barcelona, Spain, pp.243-250, 2006.

[6] Y. Fujiwara, S. Okada, T. Suzuki, Y. Ohnishi, H. Yoshida, Self-Adaptive Java Production System and Its Application to a Learning Assistance System, IEICE Trans. Inf. & Syst., Vol.E87-D, No.9,pp.2186-2194, 2004.

[7] Y. Fujiwara, S. Abe, Y. Maeda, Help Desk Architecture for a U-learning System Characterized by the Use of Probabilistic Reasoning-based Search of a Case Base, Proceedings of the 7th IASTED International Conference on Web-based Education(WBE 2008), Innsbruck, Austria, pp.57-62, 2008.

[8] T. L. Acorn, S. H. Walden, SMART: Support Management Cultivated Reasoning Technology for Compaq Customer Service, In Innovative Applications of Artificial Intelligence 4, 10th National Conf. on Artificial Intelligence, San Jose, USA, 1992.

[9] I. Watson, A. Basden, P. S. Brandon, A Client Centered Approach to the Development of Expert Systems, Expert Systems, 9(4), 1992, 181-188.

[10] J. Boron, D. Morales, P. Klah, Developing and Deploying Knowledge on a Global Scale, In Innovative Applications of Artificial Intelligence 5, 13th National Conf. on Artificial Intelligence, Portland, USA,1996.

[11] Y. Kiyota, S. Kurohashi, and F. Kido, Dialog Navigator: A Question Answering System based on Large Text Knowledge Base, Natural Language Processing, 10(4), 2003, 1-30.

[12] Y. Matsumoto, Morphologic Analysis System Chasen, IPSJ Magazine, 41(11), 2000, 1208-1214.

[13] T. Kudoh, Y. Matsumoto, Japanese Dependency Structure Analysis based on Support Vector Machine, IPSJ SIG Notes, 2000-NL-138-11, 2000, 79-86.