オンデマンド授業のスライド構造を用いた質問サジェスト方式の提案
- 批判的思考を促進する学習支援 -

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あらまし　Online learning has been widely conducted in educational institutions, which has caused students to have increasing opportunities for remote learning. In particular, on-demand classes allow students to learn at their own pace and careful consideration of their questions. We refer to the study on critical thinking, which is defined as a way of critically questioning the rationale for an idea or belief. We aim to provide on-demand class support to improve the critical thinking skills of students. To this end, this study proposes a questioning behavior support using question generation support and presentation of related slides. The question generation support helps students generate questions from the conception stage, and the presentation of related slides supports the thinking process for generated questions.

キーワード　e-Learnig, on-demand lectures, question generation, slide recommendation, presentation contents, critical thinking

1 Introduction

Critical thinking is a type of introspective thinking that consciously considers one's reasoning process [1]. Gray stated that questions are an essential part of research into critical thinking [2], and King also stated that a good questioner is a good thinker [8]. However, Ikuta et al. found that approximately 47.7% of children do not generate or ask questions [4].

Therefore, this study aims to promote critical thinking by encouraging students to generate questions and allowing the development of critical thinking skills using question generation support and a presentation of related slides.

Figure 1 shows the assumed UI of the questioning support method proposed in this study. Our proposed UI transitions from "question generation support" to "presentation of related slides" according to the student's behavior.

First, through "question suggestion support," the "target slide" of the slide that the student is currently looking at is displayed in the upper left corner. In addition, the keywords of the target slide are displayed in the upper-right corner according to the proposed method. Furthermore, when a student selects "important keyword suggestion," the keywords in the target slide are colored according to their importance, and the student can visually grasp the important keywords. In this paper, the calculation of the important keywords is described in Section 3. 1. 1.

In addition, when the student selects a "related keyword suggestion," it recommends keywords related to the selected keyword through the proposed method. The suggestion of related keywords is described in Section 3. 1. 2.

Next, at the bottom of the screen, the "question formats" are shown, as described in detail in Section 3. 1. 3.

The proposed UI for question generation support aims to support the students' ideas for generating questions. This is expected to increase the number of question ideas and questioning behaviors because students are under a state in which they are continuously suggested to generate questions.

Next, in the presentation of related slides, the right part of the screen transitions from the question generation support, and the top part shows the generated question. Furthermore, the lower part shows the slides related to the question from the proposed method. The method for presenting slides related to the question is described in section 3. 2.

2 Related research

2. 1 Proposed System Overview

In Figure 2, we show an overview of our system. The lecturer distributes the created lecture slides to the students and registers the slides in the Lecture Slide DB, a database that collects lecture materials. The learner uses this system

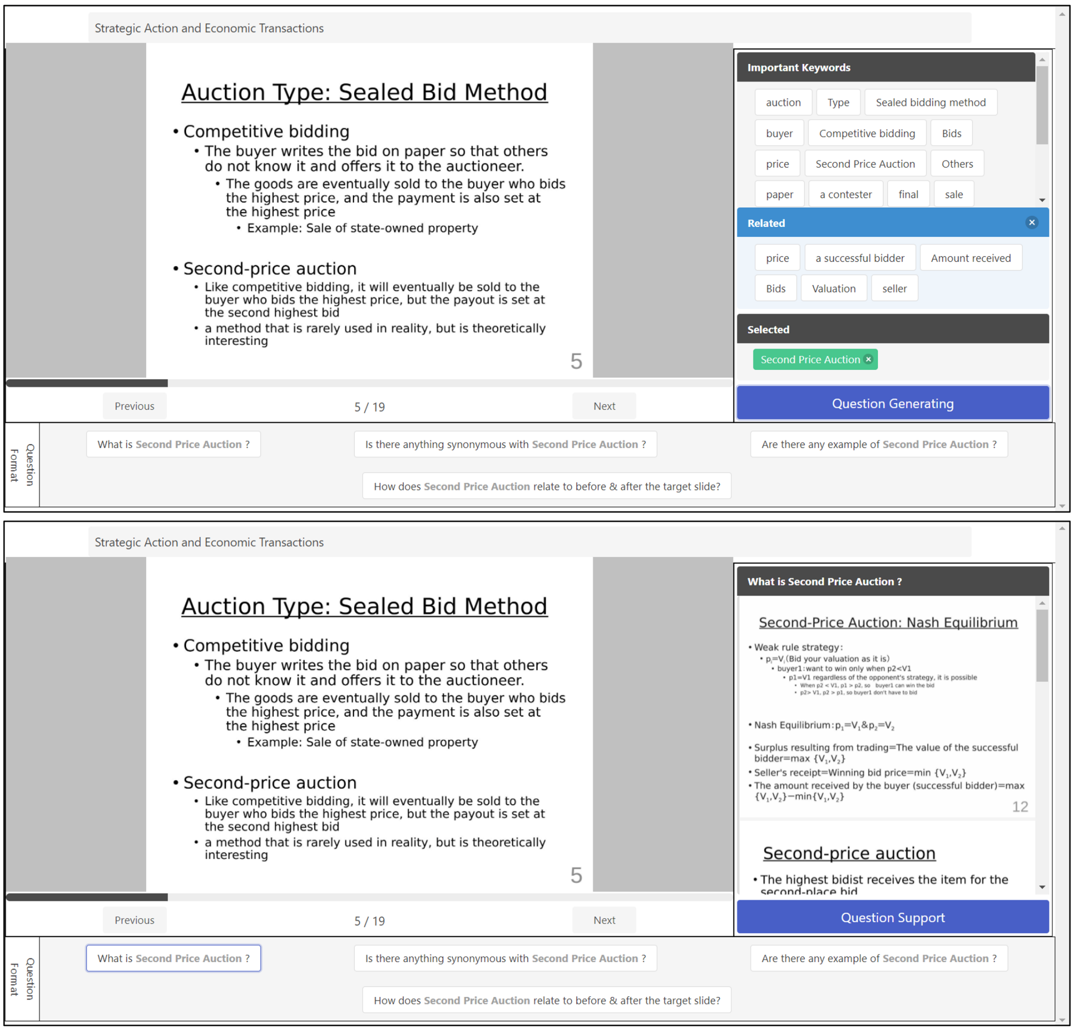

図 1 Question generation support (above) and presentation of slides related to question (below) for critical thinking

to generate questions based on the presented keywords and question formats. Then, searching of slides corresponding to the question and ranking of related slides are performed by the proposed method.

2.2 Question Generation Support

King [6] [7] and Ikuta et al. [5] proposed teaching students how to generate questions by using the question stems list to promote critical thinking. Incidentally, this list was translated into Japanese by Ikuta et al. The results of this approach show that encouraging students to generate questions for the study materials facilitates their learning. In this study, we created a keyword-based question format based on this list. In addition, we proposed a method for automatically recommending slides related to the question format.

Shinogaya et al. [10] categorized the students' questions into low- and high-level versions. In this study, we revised these definitions of low- and high-level questions for use as a keyword-based question classification frame. We redefine low-level questions as confirming facts regarding the keywords themselves, and high-level questions as facilitating the association of keywords with prior knowledge.

2.3 Structuring of the Slides

We calculated the importance of the keywords in the questions for the candidate slides by assigning values to indentation hierarchies [13] [12]. Although the value of the indentation hierarchy is based on the idea of this study, the original point of our research is to calculate and rank the importance of keywords in the target slides.

Hayama et al. [3] proposed a method of organization and structure to extract the structure information from the information presented in the slide. In addition, Mouri et al. [9] proposed a method for classifying lecture scenes into five categories. Our study differs in that it uses the structure of the slides to provide suggested questions and present related slides.

2.4 Exploration and Suggestion of Slides

In a previous study, we proposed a method of searching for

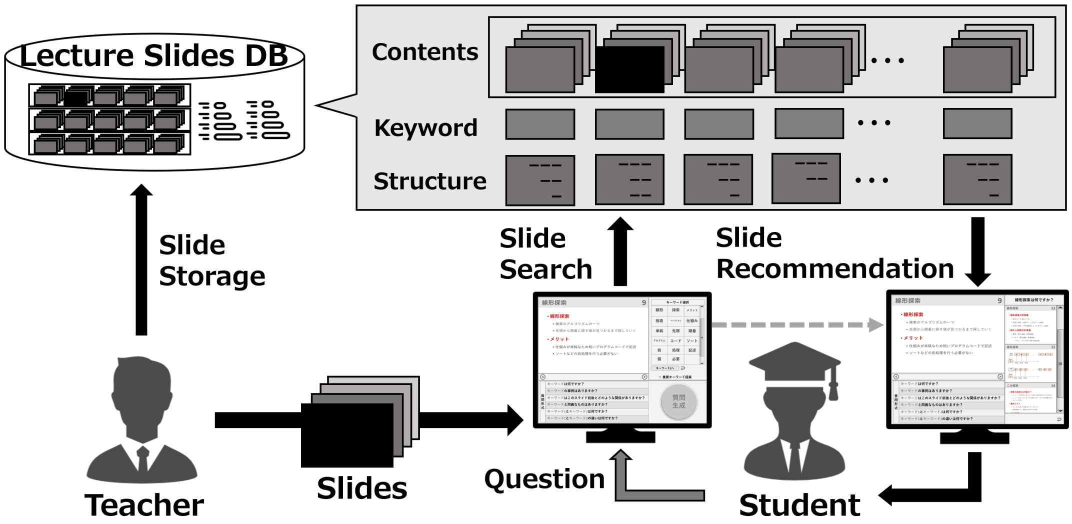

図 2　System Overview

viewing intervals between presentation content and presenting related scenes by determining the semantic relationships between the scenes based on the hierarchical structure of the slide images and the amount of speech in the video clip [11]. Our study differs in that it analyzes the relationship between the slides and questions.

We provided a context-based word cloud that summarizes the slide information, allowing students to visually understand the context of the presented content [14]. Our study is similar in that it calculates the important keywords in a slide, but differs in that the output is the slide.

3 Question Generation Support

3.1 System to Suggest Questions

3.1.1 Extraction of important question keywords

Slides used in lectures (e.g., PowerPoint and Keynote) have a hierarchical structure with an indentation. We propose ranking the question keywords by their importance using the hierarchical structure of the slide. This allows ranking of the question keywords according to their importance for student use.

The hierarchical structure of the slide is reprocessed by giving the indentation the hierarchical level we defined. As shown in Figure 3, the highest hierarchy level is $n = 1$ for the title, and the hierarchy level then increases by one level in the descending order.

First, we conduct morphological analysis and extract nouns as question keywords from the target slide. The importance of keyword k in target slide x is is calculated using the following equations.

$$I(x,k) = \alpha(x,k) \times \beta(x,k) \tag{1}$$

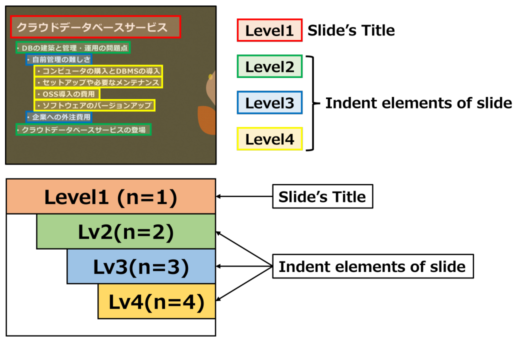

図 3　Indentation and hierarchy level examples

$$\alpha(x,k) = \sum_{n=1}^{N} \frac{1}{l_n(x,k)} \times \frac{1}{L(x,k)} \tag{2}$$

$$\beta(x,k) = \sum_{m=1}^{M} |l_m(x,k)| \times \frac{1}{M} \tag{3}$$

Here, $I(x,k)$ is the importance of keyword k in slide x.

In Eq. (2), N is a different type of an indentation hierarchy, $l_n(x,k)$ is hierarchy n where keyword k appears in slide x, and $L(x,k)$ is the total number of hierarchies in which keyword k appears in slide x.

In Eq. (3), M is the total number of indentations in slide x, and $|l_m(x,k)|$ is the total number of indentations m, where keyword k appears in slide x.

In this way, students can select the important keywords of the target slide as the question keywords.

3.1.2 Extraction of related question keywords

When students select keywords, they may want to select related keywords that do not appear on the target slide. In this case, we respond to this request by determining the relationship among the keywords in the content and extracting the upper-lower relationship between the selected and other keywords.

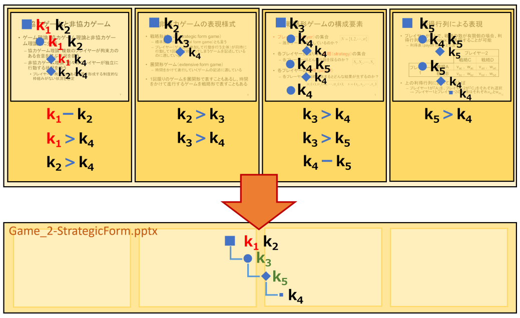

図 4 extracting the upper-subordinate relationships

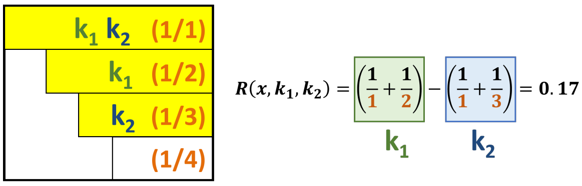

図 5 the value of the upper-subordinate

Figure 4 shows a conceptual diagram of the method proposed in this study for calculating the upper-subordinate relationship of keywords. In this study, we extracted a thesaurus in the lecture slides by using the hierarchical structure of the slides. We calculate the value of the upper-lower relationship between keywords k_1 and k_2 of slide x using the following equation:

As shown in Figure 5, we calculate the value of the upper-subordinate relationship between the keywords k_1 and k_2 in slide x by the following equation.

$$R(x,\ k_1,\ k_2) = \sum_{m=1}^{M}\left(\frac{1}{l(m,\ x,\ k_1)}\right) - \sum_{m=1}^{M}\left(\frac{1}{l(m,\ x,\ k_2)}\right) \quad (4)$$

In Eq. (4), $l(n, x, k)$ is the hierarchical level of indentation n where keyword k appears in slide x.

Then, when $R(x, k_1, k_2)$ calculated using Eq. (4) is $R(x, k_1, k_2) > 0$, it is converted in $R'(x, k_1, k_2)$= 1.00; when $R(x, k_1, k_2) = 0$, it is converted in $R'(x, k_1, k_2)$= 0.00; and when $R(x, k_1, k_2) < 0$, it is converted in $R'(x, k_1, k_2)$= −1.00. In this case, $R'(x, k_1, k_2)$ represents the upper-lower relationship between keywords k_1 and k_2 in slide X. We know that $k_1 > k_2$ for R =1.00, k_1=k_2 for R=0.00, and $k_2 > k_1$ for R=−1.00.

Finally, the value of the upper-lower relationship between keywords k_1 and k_2 in lecture C was calculated through the following equations. For this, we normalize using min-max normalization to make the calculated value lie within the range of −1.00 - 1.00.

In Eq. (6), t is the target slide that the user is viewing, and $S(t,\ k_1)$ is the total number of slides containing k_1 including target slide t.

$$R(C,\ k_1,\ k_2) = \sum_{x=1}^{X}\left(R'(x,\ k_1,\ k_2)\right) \quad (5)$$

$$R'(C,\ k_1,\ k_2) = \frac{R(C,\ k_1, k_2) + x}{x} - 1 \quad (6)$$

In this way, students can select the related keywords that appear outside the target slide.

3.1.3 Presenting the question format

Low	Q_{L_1}: What is k_1?
	Q_{L_2}: Are there any examples of k_1?
	Q_{L_3}: What are k_1 and k_2?
High	Q_{H_1}: Is there anything synonymous with k_1?
	Q_{H_2}: How does k_1 relate to before and after the target slide?
	Q_{H_3}: What is the difference between k_1 and k_2?

表 1 Question format

We proposed a question format that generates questions by simply combining keywords. The question format of Table 1 was created by referring to the question stem list created by Ikuta et al. [5] and the question classification of Shinogaya et al. [10].

In this study, we redefine low-level questions to be those that confirm the facts of the keywords themselves, and high-level questions to be those that encourage associations between keywords and prior knowledge.

In addition, we consider the case in which students select one keyword as a single keyword question, and select multiple keywords as a multiple keyword question. In the question format, Q_{L_3} and Q_{H_3} support multiple keywords.

3.2 Presentation of Slides Related to Questions

We proposed a ranking method for recommending candidate slides that are relevant to the question. The relevance is calculated by using the hierarchical structure of the slides and the occurrence rate of the keywords. The following is an example of the equation for calculating the relevant slides for question format Q_{L_1}.

a) Q_{L_1}: What is k_1?

$$Q_{L_1}(x, k) = \sum_{n=1}^{N}\frac{1}{l_n(x, k)} \times \frac{1}{L(x, k)} \times (D(x, k) + 1) \quad (7)$$

In Eq. (7), $D(x, k)$ is the number of indentations at the lower hierarchical level where keyword k appears in slide x, $l_n(x, k)$ is the hierarchy level n at which keyword k appears in slide x, and $L(x, k)$ denotes the number of levels where keyword k appears in slide x.

b) Q_{L_2}:Are there any examples of k_1?

$$Q_{L_2}(x,k) = L_m(x,k) \times \frac{1}{M(x)} \tag{8}$$

In Eq.(8), $L_m(x,k)$ is the number of indentations where the keyword k appears in slide x. $M(x)$ is the total number of indentations on slide x.

c) Q_{H_1}: Is there anything synonymous with k_1?

$$Q_{H_1}(x_{target}, x, k) = \sum_{n=1}^{N} \frac{1}{|l_n(x_{target}) - l_n(x,k)| + 1} \tag{9}$$

In Eq.(9), $l_n\ (x_{target}, k)$ is the hierarchy level n where the keyword k first appears in the target slide. $l_n(x,k)$ is the hierarchy level n at which the keyword k first appears in slide x.

d) Q_{H_2}: How does k_1 relate to before and after the target slide?

$$Q_{H_2}^{Before}(x,k) = \sum_{n=1}^{N} \frac{1}{l_n(x,k)} \times \frac{1}{L(x,k)} \times (D(x,k)+1) \tag{10}$$

$$Q_{H_2}^{After}(x,k) = \sum_{n=1}^{N} \frac{1}{l_n(x,k)} \times \frac{1}{L(x,k)} \tag{11}$$

The recommended candidate slides before the target slide are calculated by Eq.(10), and after the target slide are calculated by Eq.(11).

In Eqs.(10) and (11), $D(x,k)$ is the number of lower hierarchical levels of the occurrence hierarchy of keyword k in slide $x.l_n(x,k)$ is the hierarchy level n at which the keyword k appears in slide x. $L(x,k)$ is the number of levels where the keyword k appears in the slide x.

e) Q_{L_3}: What is the difference between k_1 and k_2?

$$Q_{L_3}(x,k_1,k_2) = w_1 \sum_{n=1}^{N} \left(\frac{1}{l_n(x,k_1,k_2)} \times \frac{1}{N(x)} \right) + w_2 \left(\frac{L(x,k_1)}{F_{k_1}} + \frac{L(x,k_2)}{F_{k_2}} \right) \tag{12}$$

In Eq.(12), the weights are defined as $w_1 + w_2 = 1.00$. Since we have not studied the optimal weights, we tentatively set $w_1 = 0.50, w_2 = 0.50$. F_k is the hierarchical level at which the keyword k first appears in the target slide. $l_n\ (x,\ k_1,k_2)$ is the hierarchy level n at which the keywords k_1 and k_2 appear in slide x. $L(x,k)$ is the hierarchy level where the keyword k first appears in slide x.

f) Q_{H_3}:What is the difference between k_1 and k_2?

$$Q_{H_3}(x,k_1,k_2) = \sum_{n=1}^{n} \frac{l_n(x,k_1,k_2)}{N(x)} + \left(\frac{F_{k_1}}{L(x,k_1)} + \frac{F_{k_2}}{L(x,k_2)} \right) \tag{13}$$

In Eq.(13), F_k is the hierarchical level at which the keyword k first appears in the target slide. $l_n\ (x,\ k_1,k_2)$ is the hierarchical level n at which the keywords k_1 and k_2 in slide x appeared in the same slide. $L(x,k)$ is the number of levels where the keyword k appears in slide x.

4 Evaluation experiment

Five students evaluated our proposed method through a questionnaire using a Google form.

a) Important Keyword Calculation

The subjects viewed the target slide and rated the importance of all keywords appearing in it. The response method uses a five-point scale from "very unimportant" to "very important." The importance ranking of keywords through a user evaluation and the ranking using the proposed method were compared based on the application of Spearman's rank correlation. The result was calculated as 0.77, which shows a high correlation.

b) the question format

The subjects were presented with each of the six question formats and definitions of the low and high-level questions stated in section 3.1.3. They were given a choice of which definition they thought fit each question form. As shown in Table 2, the scores are 0.80 for the entire question format, 0.73 for the low-level questions, and 0.87 for the high-level questions. Therefore, we consider the classification of the question format to be appropriate.

c) Presentation of Slides Related to Questions

To evaluate the slide presentation provided in section 3.2, we investigated whether the recommended candidate slides presented by the proposed method were useful for the understanding of the students. As a preliminary survey, we ask students about their learning experiences related to the slides. We present the students with the questions generated by the proposed method. The subjects rated the recommended candidate slides in terms of understanding the keyword on a 5-point scale from "very difficult" to "very easy". The lecture slides are hypothetical slides created by the author, of which there are two types: "Basics of Natural Language Processing" and "Game Theory." The ranking of the recommended candidate slides calculated using the equation applied through the proposed method and the ranking through the student evaluation of the questionnaire are compared by applying Spearman's rank correlation. The results are shown in Table 3. We show the results separately for

表 2 Low- and high-level classifications in question format

Question Format	Low	High	rate	Ave	Overall Ave
Q_{L_1}: What is k_1?	4	1	0.80	**0.73**	**0.80**
Q_{L_2}: Are there any examples of k_1?	3	2	0.60		
Q_{L_3}: What are k_1 and k_2?	4	1	0.80		
Q_{H_1}: Is there anything synonymous with k_1?	3	2	0.40	**0.80**	
Q_{H_2}: How does k_1 relate to before and after the target slide?	0	5	1.00		
Q_{H_3}: What is the difference between k_1 and k_2?	0	5	1.00		

表 3 Rank correlation between the proposed method and the evaluation experiments

Number of Selected Keywords	single						Multi	
Question Format	Q_{L_1}	Q_{L_2}	**Ave**	Q_{H_1}	Q_{H_2}	**Ave**	Q_{L_3}	Q_{H_3}
Lecture Slides "Basics of Natural Language Processing"	0.40	0.50	**0.45**	0.90	0.50	**0.70**	-0.90	0.90
Lecture Slides "Game Theory and Auctions"	0.85	-0.05	**0.40**	0.35	0.95	**0.65**	0.00	-0.33

questions with one or more selected keywords. The single lower-level questions have a mean of 0.45 and 0.40 for each of the two lectures, and the single higher-level questions have a mean of 0.70 and 0.65; thus, we conclude that both single questions are positively correlated. By contrast, the multiple lower-level questions have values of −0.90 and 0.00, and the multiple higher-level questions have values of 0.90 and −0.33, which indicates that there is either no correlation or a negative correlation.

Q_{L_1}: Keywords that appear in the upper level of the hierarchy and have a lower indentation should be ranked highly, and it was correctly judged.

Q_{L_2}: Keywords appeared in the top level of the hierarchy, and especially when a keyword appeared in the title, the ranking should be high, and this was judged correctly, but in the future, the weight of the title should be considered.

Q_{H_1}: Keywords should be ranked highly if they are indented in the same hierarchy as the hierarchy in which they appeared. However, the proposed formula is insufficient because it only considers the occurrence of keywords in the upper hierarchy. In the future, we should consider the number of indentations in the hierarchy where the keywords appear.

Q_{H_2}: The keywords should be ranked highly if they appear in the upper hierarchy and the hierarchy in which they appear has a lower indentation, which was correctly determined. On the other hand, there was little relationship between how the keywords were related to the before and after slides. In the future, we should consider whether the formula should be changed before or after the target slide.

Q_{L_3}, Q_{H_3}: In both cases, the keywords appear in the upper-level hierarchy, and the keywords should be ranked higher if they have a lower indentation in the hierarchy, and Eqs.(12) and (13) are insufficient. In particular, it is quite difficult for multiple selected keywords to appear in the same hierarchy, and the first term was not reflected well in the calculation of Eq.(12). In the future, we should consider whether the selected keywords are included in the whole slide.

5 Conclusion

In this study, we proposed online learning support that facilitates students' questioning behavior by assisting question generation that supports question recall and recommending related slides automatically to think about their questions, and develops critical thinking ability. Furthermore, we conducted an evaluation experiment and its discussion as a preliminary study for the system construction in the conceptual stage.

As a result of the evaluation experiment, we confirmed that the calculation of the importance and the presentation of the ranking of the slides corresponding to the single keyword questions proposed in this study are effective. In the future, we would like to improve the question format and calculation formulas, handle compound words, examine the rate of change of values among slides, consider page groups of multiple slides, and conduct evaluation experiments on a larger scale. In addition, we are planning to implement metadata extraction of slides and database construction in the future.

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