Probabilistic Question Selection Approach for AR-based Inorganic Chemistry Learning Support System

Masaru OKAMOTO[a*], Ryoya SUMIDA[a] & Yukihiro MATSUBARA[a]
[a]*Graduate School of Information Sciences, Hiroshima City University, Japan*
*okamoto@hiroshima-cu.ac.jp

Abstract: In this paper, we proposed AR-based learning support system using user's learning history information for inorganic chemistry with probabilistic question selection algorithm based on learner's operation in the virtual environment. In order to perform experiments in the virtual environment, markers and USB camera are utilized as input interface. By using this interface, a learner can perform the chemical experiments in the virtual environment. For chemical experiments, the proposed system gives some questions to a learner. These questions are selected based on a leaner's learning history information. This selection algorithm helps a learner performing the experiments corresponding to suitable questions for his/her learning about inorganic chemistry. For selecting a set of questions, probabilistic question selection algorithm is proposed. By using this selection algorithm, a learner can learn repeatedly about inorganic chemistry in the virtual environment. The validity of the proposed system and algorithm was shown as experimental results of subject's learning result.

Keywords: Augmented Reality (AR), Experiment-based Learning, Selection of suitable Questions, Inorganic Chemistry, Probabilistic approach

1. Introduction

In Japanese high school, chemical education consists of 3 parts (theoretical chemistry, organic chemistry and inorganic chemistry). Particularly, it is important for learners to perform various chemical experiment in the classroom for learn chemical reaction. However, it is too difficult for learners to learn all knowledge about chemical reaction in one experiment. And it is impossible that all experiments are repeatedly performed until all students memorize all chemical reactions. In order to improve these problems, learning support systems using virtual experiment are developed (Konishi *et al.* (2010) and Nanko *et al.* (2008)).

On the other hand, it is important for learners to observe an experimental result (for example, colors) and process of experiments in Japanese high school education. Before now, in order to learning the inorganic chemistry based on virtual experiment, we developed AR-based learning support system (Sumida *et al.* (2012)). AR is helpful in order to make a natural user interface which integrated VR and real world (Asai *et al.* (2011), Iwasaki *et al.* (2010), Sano *et al.* (2010), Santos *et al.* (2014) and Okada *et al.* (2013)). In order to perform experiments in virtual environment, markers printed on papers are utilized as control interface. By user's operation of markers, user can perform various experiments (such as flame test). Additionally, so the system can give questions and hints, user acquires knowledge of chemical reaction by solving questions in virtual environment. However, for learning the knowledge of inorganic chemistry using only this AR-based learning support system, learners have to select some question about inorganic chemical reactions. Then we developed question recommendation method for this system (Okamoto *et al.* (2013)). By using this approach, it is expected that they can perform their learning process more effectively. However learner has to solve paper test to give the system some information about learner understands.

In this paper, we proposed probabilistic question selection method based on learner's operation in the virtual environment for AR-based learning support system. Given questions are probabilistically determined by learner's operation information. This information is calculated from user's operation in the virtual environment. By learning repeatedly using this system and given questions, it is expected that the learner can memorize all chemical reactions corresponding to prepared questions.

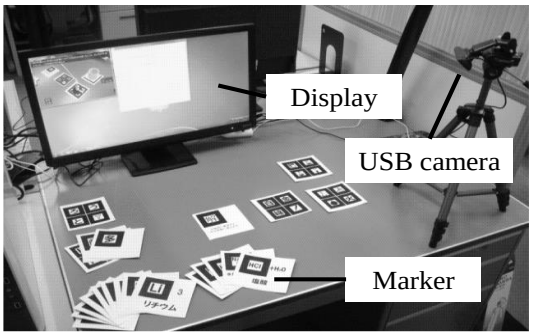


Figure 1: The Overview of the Proposed System.

2. 2. Inorganic chemistry learning management system using AR-based virtual laboratory

2.1 System Structure

Figure 1 shows the overview and structure of the proposed system respectively. As shown in Figure 1, this system has three devices (1: USB camera, 2: computer and display, 3: markers for input interface). USB camera records image of user's operation in order to create the virtual environment for experiments based on real image and CGs. Simulation of experiments and creation of virtual environment are carried out by computer. In order to construct the virtual laboratory from real image recorded by USB camera, user's operation must be recognized from real image. Then various markers are utilized for recognition of user's operation. By putting and moving markers in recorded area, user's operation are easily recognized by the system. For recognition of markers from image recorded by USB camera, ARToolKit library and markers are utilized. Table 1 shows examples of markers used in the virtual environment. By putting these marker in recorded area, this system understand that user utilize the corresponding instruments. Additionally corresponding CGs are displayed near the marker in virtual environment (shown in Figure 1). Then, solutes and water solutions have to be selected for performing experiments which user wants to conduct. The operation markers shown in Table 2 are used for showing user's intention of operation.

Table 1: Examples of Markers Corresponding to Instruments and Item for Experiment.

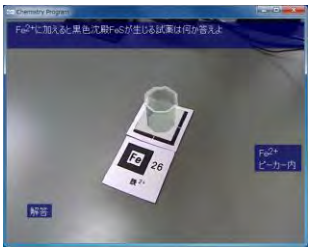
	Instruments	Solutes	Water solutions
An Example Image of Markers			

Table 2: Examples of Markers Corresponding to Operation by Learner.

	Operation for water solutions	Adjustment of Solutes' parameters	Checking leaner's result of experiment as answer
An Example Image of Markers			

2.2 AR-based Virtual Environment with Giving Questions Function

In this system, in order to perform the chemical experiments, the virtual environment is utilized. By using this environment, learner can perform three chemical experiments (1: flame color test, 2: precipitation of ion, 3: positive ion analysis). The system understands the type of experiments which learner wants to conduct from the arrangement of the instruments markers. Next, an example of the virtual experiment is described.



(a) Preparation of water solution which contain ferric ion

(b) Adding the precipitating agent for making precipitation of ion

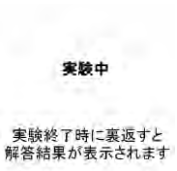
Figure 2: Example of Experimental Process about Precipitation of Ion.

An example precipitation of ion experiment is shown in Figure 2. In this experiment, user has to investigate the phenomenon about the color precipitation of ion, used precipitating agent and so on. In order to conduct this experiment in virtual environment, user should use the three kinds of marker (instruments marker, solutes marker and water solutions marker). In the example of experiment shown in Figure 2, at first, water solution that contains the ferric ion is prepared in beaker (Figure 2(a)). For this preparation, ferric ion marker is put and moved near the beaker marker. In next process, by adding the precipitating agent into the beaker, user can check the precipitation of ion. Then a water solution maker is put and moved near a beaker marker (Figure 2(b)). By this operation, corresponding water solution (hydrogen sulfide solution) is added into prepared solution in virtual environment. By conducting the experiment corresponding to phenomena which can indicate the information that user wants to know, user can learn about precipitation phenomena through the experiments.

2.3 Giving Questions Function

(a) An example of presentation of a question in virtual environment

(checking the result of experiment)



(during experiment)

(b) Checking marker

Figure 3: Question and Marker for Checking Answer.

In this subsection, question-based learning approach is described. The question is displayed on the upper part of virtual environment. Figure 3(a) shows an example of presentation of question in virtual environment. In this question, "What is ion which can change the color of flame into blue-green?" is written in Japanese. When checking marker (Figure 3(b)) is turned, system

evaluates the answer (result of experiment). If user makes mistake, hint is displayed on the underside of virtual environment and user perform experiment again based on given hint. After having a correct answer, by turning this marker again, next question is given for user.

2.4 Probabilistic Questions Selecting Approach based on Learner's Process of Experiment

In the proposed system, a set of question is given to each learner for leaning the chemical reactions through answering process. To performing learning effectively, suitable questions have to be selected. By finding answers of given questions through experiments in the virtual environment, it is expected that the leaner can acquire the knowledge corresponding to given questions. Questions selection algorithm is shown as below. Then, in this algorithm, the number of questions in one set is set as Q.

1. At first, parameters $V_1(l)$, $V_2(n)$, and $V_3(m)$ are initialized.
2. A learner performs experiment in the virtual environment for answering given questions.
3. After experiment, parameter $V_1(l)$ is calculated. If experimental process of each given questions is applied for some conditions, the corresponding weights are added to each parameter $V_1(l)$. The all conditions and corresponding weights are shown in Table 3.
4. The parameters $V_2(m)$ are calculated. Then m is a number of the question which is not applied to all conditions in Table 3. And the parameters $V_3(n)$ is determined, where m is question number which is not given once. Then, $V_2(m)$ and $V_3(n)$ are constant number. $V_2(n)$ is set as $\alpha V_3(n)$ $(0 < \alpha \le 1)$.
5. The parameters ($V_1(l)$, $V_2(m)$, $V_3(n)$) and the probabilities for all questions (P_1(l), $P_2(m)$, $P_3(n)$) are calculated as follow equations.

$$V_1(l) = \begin{cases} 0, & q = 0 \\ \sum_{d=1}^{D} W(d) count_d(l), & o.w. \end{cases}$$

$$V_2(m) = \begin{cases} \alpha, & q = 0 \\ \dfrac{\alpha(Q-q)\sum_{l \in \mathbf{L}} V_1(l)}{q(\alpha\|\mathbf{M}\| + \|\mathbf{N}\|)}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$V_3(n) = \begin{cases} 1, & q = 0 \\ \dfrac{(Q-q)\sum_{l \in \mathbf{L}} V_1(l)}{q(\alpha\|\mathbf{M}\| + \|\mathbf{N}\|)}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$P_1(l) = \begin{cases} 0, & q = 0 \\ \dfrac{V_1(l)}{V}, & o.w. \end{cases}$$

$$P_2(m) = \begin{cases} \dfrac{\alpha}{V}, & q = 0 \\ \dfrac{V_2(m)}{V}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$P_3(n) = \begin{cases} \dfrac{1}{V}, & q = 0 \\ \dfrac{V_3(n)}{V}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

, where q is the number of questions selected from a set of the question applicable to the conditions of the Table 3. **M** and **N** are set of n and m respectively. Intersection of **M** and **N** is empty set. And V is calculated as follow equation.

$$V = \sum_{l \in L} V_1(l) + \sum_{m \in \mathbf{M}} V_2(m) + \sum_{n \in \mathbf{N}} V_3(n)$$

6. Based on calculated probabilities $P_1(l)$, q questions are selected. And, Q-q questions are selected based on Probabilities $P_2(m)$ and $P_3(n)$. In the next experiment, selected questions are given to learner in the virtual environment.

Table 3: Conditions and Corresponding Weights for Probabilistic Estimation.

Conditions	Weights(W(d))
Condition 1: The number of times of trial is larger than one.	W(1) = 6.8
Condition 2: Experiment time is 11.75 seconds longer than the average of other experiment time.	W(2) = 3.4
Condition 3: Answer time is 18.1 seconds longer than the average of other answer time.	W(3) = 5.0
Condition 4: The number of incorrect answer is larger than one.	W(4) = 7.8

3. Evaluation Experiment

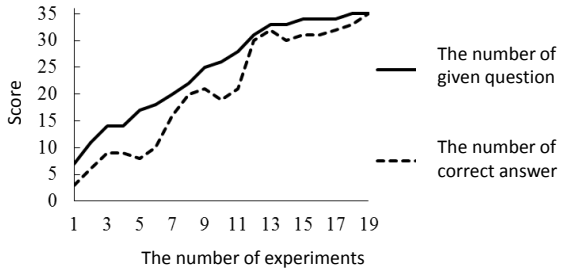


Figure 4: Experimental Results of Subject A in Paper Test.

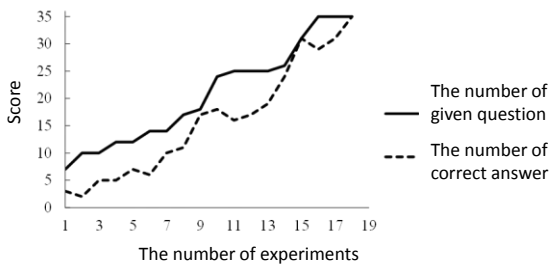


Figure 5: Experimental Results of Subject B in Paper Test.

In order to evaluate the effectiveness of proposed probabilistic selection of given questions and learning process using virtual environment, learning experiments about chemical reaction were conducted. Two subjects (A and B) participated in the experiments. Subject A learned about the knowledge of the chemical reaction using the proposed system. As a candidate for comparison, subject B used the previous systems (Okamoto (2013)). The previous system uses the paper test result of learner to determine the set of questions. And, Q was set as 7. The total number of given questions in this experiment is 35.

The results of the experiments of subject A is shown in Figure 4. For comparison, Subject A took paper test after each experiment. By learning repeatedly, in the 19th experiment, the subject A has acquired all the knowledge of chemical reactions corresponding to all questions given to subject A in the virtual environment. Next, to compare with a proposed system,

experimental result of Subject B is shown in Figure 5. As shown in this figure, the subject B's learning experiment is ended by 19 times too. The learning result of Subject B is similar to Subject A's result. However, total learning time of Subject B using the previous system is longer than Subject A's total time using the proposed system, because by using the proposed system, the questions are given to learner's without performing some paper test before each virtual experiments. From these results, by performing repeatedly learning using proposed questions selection algorithm and virtual environment, there is possibility that a learner can get all knowledge of inorganic chemical reaction which the Japanese high school students have to study.

4. Conclusions

This paper proposed probabilistic question selection approach based on a learner's learning history in the virtual environment. For chemical experiments, the proposed system gives some questions to a learner. These questions are probabilistically selected based on a leaner's learning history information. The validity of the learning system based on proposed approach was shown as experimental results of 2 subjects' learning result. In future works, we would like to perform additional experiments to show the statistical analysis of proposed approach and system.

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