Construction of Recommender System based on Cognitive Model for "Self-Reflection"

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ABSTRACT
Every human processes a set of mental schemas for problem solving. We develop and improve these schemas by reflecting on our experiences with errors, which is a type of metacognition (Kayashima, 2008). In this study, we proposed a cognitive model of this "self-reflection" process based on Kayashima's two-layer working memory model, and developed a food recommender system using our cognitive model. In the test simulation, the users were satisfied with the foods that the system recommended, although the recommendation results were unexpected to the users. This implied the system practically worked to satisfy the user's expectation. On the other hand, the candidate recommendations which the system selected as its final output were different from those provided by the users. This suggests that the cognitive model needs improvement in terms of psychological reality.

Author Keywords
self-reflection; cognitive model; recommender system; meta-cognition.

INTRODUCTION
It is important for human beings to acquire problem solving skills to deal with the various problems that they face each day. Metacognition can be defined as the human ability to acquire such problem solving skills [1, 2]. By using metacognition, human beings can observe and improve the problem-solving strategies that they apply. In general, humans avoid committing the same mistakes by improving their strategies. However, it is not clear how people use failure experiences for metacognition and how they improve problem-solving strategies. In this research, we define the refinement of problem-solving skills based on human failure experiences as self-reflection, and attempt to construct a cognitive model expressing the self-reflection process.

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Self-reflection is a cognitive activity that is performed internally. We aim to construct a cognitive model expressing the self-reflection process, oriented towards the constructive approach. In this study, we deal the task of food recommendation. Generally, in this domain, it is difficult for the recommender system of a content-based filtering method to make unexpected but satisfying recommendations to the user. This problem is caused by the fact that human preferences are dynamic, even if the system builds a preference model based on the user's history. In this case, the self-reflection function should be able to modify the system to adapt to the user's preferences.

PROPOSED MODEL

Kayashima's model for problem solving: Two Layer Working Memory Model
Many literatures have dealt with metacognition, especially the learning support for metacognitive activities in the field of Artificial Intelligence in Education and Learning Science. Kayashima et al. [3] provided an explicit description for metacognitive activities and proposed the two-layer WM model. This model provides an explanation for the mechanism of cognitive operation (e.g. observation) to cognitive activity, and in this point, this model can be effective to represent the self-reflection process as well.

The model assumed that general problem-solving is a state of transition of the WM influenced by five cognitive activities: "observation," "rehearsal," "evaluation," "virtual application," and "selection." Observation involves carefully looking at the subject and generating the model as the product in the WM. Rehearsal involves keeping the product in the WM to support complicated cognitive operations. Evaluation involves making it possible to search for applicable operators from the knowledge base. The virtual application involves virtually executing an applicable operator in the knowledge base to generate an action list. Selection involves selecting an optimal operator from the results of the virtual application and generating a list of operators to actually apply (action list). When applying the generated action list, the WM's products shifts to new products.

In the WM upper layer, metacognitive activities can be described as cognitive activities that observe and coordinate cognitive activities performed in the WM lower layer. There are two ways to generate products from this metacognitive activity: reflection *in* action and reflection *on* action. The former involves coordinating the cognitive operation in the lower layer and observation thereof in parallel, and generating the observation results in the upper layer as a product. The latter involves observing the products (i.e., cognitive operation process to a product) in the lower layer and generating the process as a product in the upper layer.

Proposed model for problem solving

We attempted to model self-reflection based on the two-layer WM model. Our model focuses on the reflection on action. Previous studies suggest that the failure experience lets humans generate, transpose, and improve strategies [4, 5]. Chiken et al. [6] suggested that strategies are generated by knowledge construction from the failure experience. They also suggested that failure knowledge can be organized into six categories: event, background, process, cause, coping, and summary. In other words, the reflection on action process implies the acquisition of metacognitive knowledge by organizing the failure experience from these categories [7]. Above all, self-reflection is defined as "constructing a strategy by reflection on action through the construction of failure knowledge."

A conceptual model of self-reflection is shown in Figure 1. The model shows that 1) failure feedback triggers the construction of the failure knowledge. 2) To identify the cause product, trial and error of coping (through virtual application) and observation of the result are carried out. 3) As the cause is specified, the background, coping, and cause product are associated with each other. Finally, 4) the association is stored in long-term memory (LTM). The stored strategies in LTM can be easily accessed to adjust cognitive operations in the WM lower layer during the next problem resolution (i.e., reflection in action).

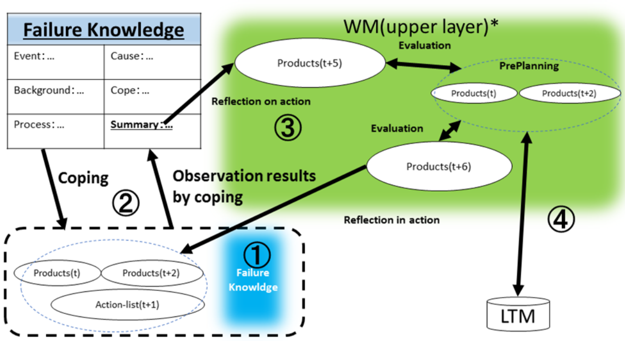

Figure 1. Conceptual model for self-reflection

SYSTEM IMPLEMENTATION

Food recommendation function

The food recommendation function performs cognitive operations in the WM lower layer in Kayashima's model. The problem-solving task of the system can be stated as reducing the number of food recommendation candidates using the cognitive operation module. Then, a food recommendation candidate is regarded as a product of this system. For this system, we built an observation, virtual application, and selection modules.

The observation module observes the conditions of the food recommendation task. It receives context information as input from the user and then selects two contexts that the user might consider important. It's suggested that contextual information should work in recommender systems [8]. The virtual application module narrows down the recommendation candidates, which is the product, based on the observation results. We implemented three methods to determine the food candidates whose context values are 1) close to the user's input values, 2) high, and 3) low. This module generates three types of candidates. The selection module compares each output and then identifies the candidate as next product that meets the user's preference.

The database of meals used for the recommendations of this system was constructed based on a questionnaire survey. One hundred two culinary genres were selected from the most specific culinary genre registered in Tabelog (https://tabelog.com/cat_lst/, 2016/09/01). Fourteen subjects were asked to assign the corresponding context values when deciding what food to eat (e.g. "when you decide to eat pizza, your budget is…") using a 10-point Likert Scale. The context represented the budget, outside temperature he/she felt, number of people to eat with, time passed since he/she woke, and degree of hunger. These context values represent the conditions based on which the food will be chosen. Each food in database had the average context values.

"Self-reflection" function

The self-reflection function is represented by two modules: reflection module and conscious observation module. The reflection module generates and improves strategies based on failure knowledge. The failure knowledge construction begins as the user refuses a recommendation. Specifically, the food recommendation function is repeated. In this case, the combination of all the contexts (here called "virtual-context") is used (i.e., $5 \times 4 = 20$ foods were chosen), and all results are arranged in a list. When the list is displayed to the user, the user selects one food from the list. Then, the module determines the cause product from the selected food, in comparison to recommended food. The cause product can be referred to as the "context of interest" in recommendation or "narrowing down method." If the context of interest is the same as the context of recommended food, the narrowing down method that the system adapted is considered as the cause product of the failure experience.

The conscious observation module adjusts the meal recommendation function based on the strategies constructed in the reflection module. This module works whenever a similar situation as that of a recommendation failure occurs at the start of the recommendation. When the conscious observation module is activated, it displays to the user which part of the internal processing of the food recommendation by the system was changed. For example, the system said *"*I previously made a mistake in a similar situation. The recom-

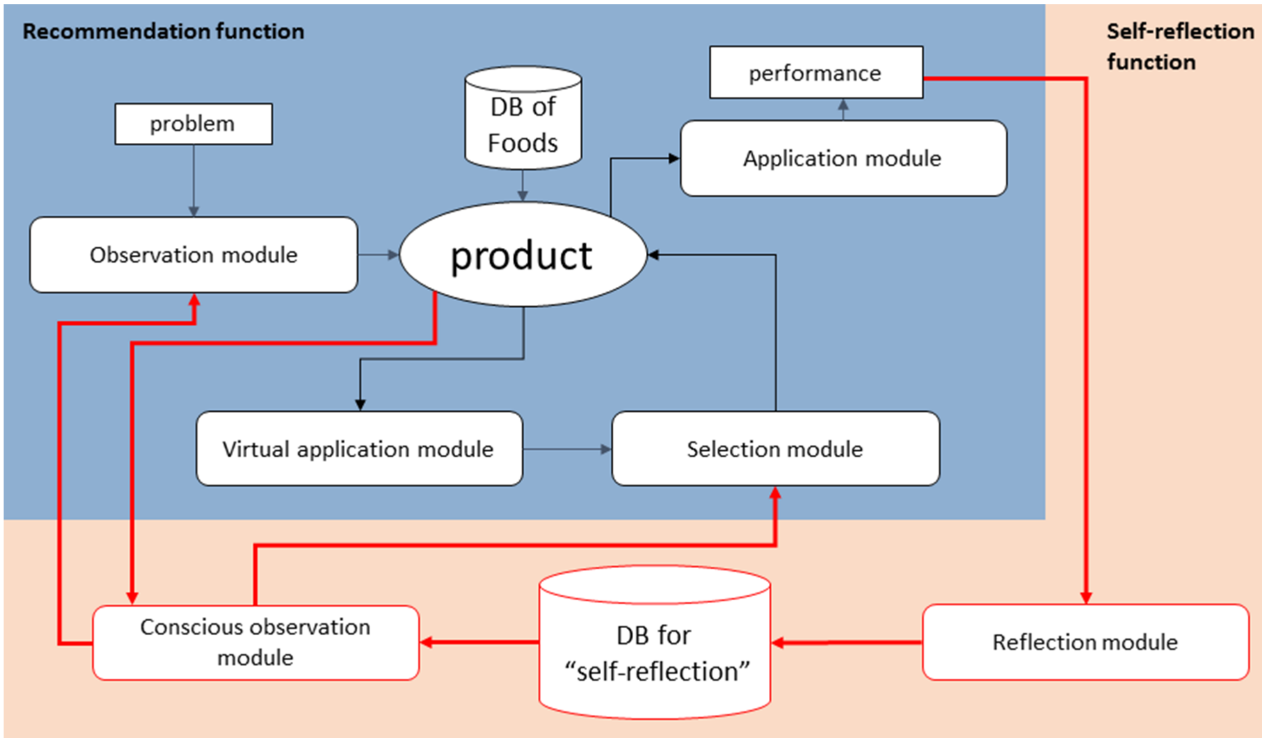

Figure 2. System diagram: The blue and orange part indicate the recommendation and self-reflection function, respectively.

mended food was yakisoba but you preferred yakiniku. *I should have taken into consideration the budget and the number of persons eating with you. Perhaps, the number of persons is important to you! Therefore, in this case, …"*

EXPERIMENT 1

Purpose

The purpose of this experiment is to verify the usefulness of the reflection function and to collect the items recommended by the system for assessing the metacognitive model (ref. Section "Experiment 2").

Procedure

Fifteen subjects (college students, graduate students, and social workers; 10 males, 5 females) participated in the experiment to interact with the system. They were asked to determine their own 10 dietary situations with the given context and received recommendations (10 times for each participant). They decided whether or not to accept the recommendations in each trial. After the interaction, participants were asked to evaluate the degree of 1) satisfaction and 2) unexpectedness of each recommendation with a 10-point Likert scale. In addition, we defined the recommendation acceptance rate to assess the reflective system. We also constructed a general system and a random system to evaluate the verification of the self-reflection module. The general system removes the self-reflection function from the reflective system. On the other hand, the random system decides on all recommendations randomly from the database. Each system also displays the internal processing. For example, the general system presents recom-

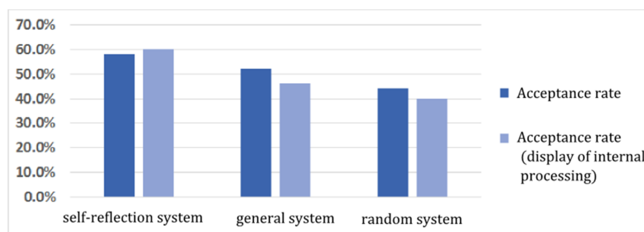

Figure 3. Acceptance rate of each system

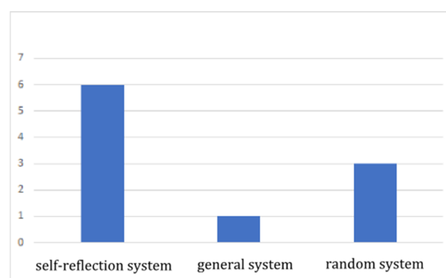

Figure 4. Number of the recommended items whose unexpectedness and satisfaction were evaluated more than 7

mendations such as, *"… This time, I changed the recommendation strategy, that is, I recommend food that everyone, in this case, chooses. So, in this case, …."*

Results

The recommendation acceptance rate for each system is shown in Figure 3. The vertical and the horizontal axes represent the recommendation acceptance rates (%) and each system, respectively. The graphs indicate that the acceptance rate of the reflective system was higher than that of the other systems. This tendency was enhanced when each system displayed the internal processing.

Figure 4 shows the number of recommendations whose satisfactory and unexpectedness were rated as 7 or higher for each system. The graphs indicate that the subjects who interacted with the reflection system tended to highly appreciate the unexpectedness and satisfaction provided by the system recommendations, compared with subjects who interacted with the other systems.

EXPERIMENT 2

Purpose

The purpose of Experiment 2 is to evaluate the validity of the self-reflection model. Because metacognitive activity cannot be observed, we compared the action list of the products (i.e., food candidates) of the system and humans.

Procedure

Three university students (2 males, 1 female) participated in the experiment and were asked to provide food recommendations 10 times to the person with the console (in a chat system). They were instructed to select the foods from the database two times, lining up the candidates and their contexts of interest. We compared the outcomes with the recommendation candidates and contexts of interest generated by the system in Experiment 1.

Results

The contexts of interest that participants reported in their self-reflection were different from that of our system. To assess the reflection module, we applied the participants' contexts of interest to the recommended module to extract the food candidates. Comparisons between the extracted food candidates and user's candidates show that the matching rates between some recommendation candidates on the list rose by as much as 40%. On the other hand, the matching rates for other recommendations decreased.

The characteristic of reflection behaviors presented as the result of an interview are as follows:

- In the second session, he/she seems to consider of his/her budget and number of persons to eat with. Therefore, this time, I recommended foods that were not too expensive and good for sharing with two persons.
- In a similar situation as the second session, I made slightly better recommendations. Hence, I recommended foods based on the degree of hunger. As he/she seems not to mention other context, the budget is taken care of anyway.

DISCUSSION

The participants who interacted with the self-reflection system tended to rate both unexpectedness and satisfaction higher than other recommender systems. The participants also accepted system recommendations, especially those of the self-reflection system. Therefore, our self-reflection system can satisfy their demands.

On the other hand, the results from the Experiment 2 indicate that the candidates generated by the system did not match those generated by participants, which implies that our self-reflection model did not follow the human self-reflection. This result suggests that the high acceptance rate and appreciation of unexpectedness and satisfaction should rely on anything other than the reflection function itself. Experiment 1 showed that the acceptance rate was higher when the system displayed the internal processing to users. Thus, it can be assumed that the display of the system influenced participant's high acceptance rate. As the system behaved as if it was engaged in self-reflection, participants could treat the system as a social being [9]. Such visual performance can help participants accept recommendations.

Another role played by the display of internal processing is encouraging appreciation for unexpectedness and satisfaction. In general, content-based recommender systems have difficulty in recommending the unexpected to users [10]. Our self-reflection system, however, provided such unexpected recommendations. The display contributed to participant's expectation that the system learned his/her preferences. Displaying the internal processing of the reflection system showed which processes and how the system changed based on the failure experience. From this point of view, participants predicted the internal processing model of the system (the rules the system acquired in accordance with their preference). Despite this, when the system recommended foods that were different from what they expected, the unexpectedness was enhanced. When the recommended food was appropriate for the situation they specified, they appreciated the system and were satisfied.

CONCLUSION

In this study, we proposed a cognitive model representing the self-reflection process and implemented it in a food recommender system. We conducted experiments to assess the system and the results indicated that the recommended foods were highly unexpected and satisfying for users. It was also suggested that displaying the internal processing of the system contributed to its high-performance rating from users. The display encouraged participants to believe that the system was learning in accordance with their preferences. On the other hand, the cognitive model was evaluated based on the consistency between food candidates selected by the system and the participants. The results showed that the selected foods were different from each other although both shared the self-reflection process in food recommendation, and that they modified the contexts of interest based on the failure experience.

In future work, we plan to address the following issues. The first is the experimental limitations. In the experiments, it was unclear whether situations participants assumed reflected actual situations. Furthermore, it is also important to study the reflection process in the learning context and consider the metacognitive model to explain the learner's reflection process.

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