Generation Method of Multiple-Choice Cloze Exercises in Computer-Support for English-Grammar Learning

Ayse Saliha Sunar, Dai Inagi, Yuki Hayashi, and Toyohide Watanabe

Abstract. With many remarkable advances in technology, not only studying with tutor at school but also studying through computer at home become preferable. Intelligent Tutoring System (ITS) is one of the research fields which aim to support the individual learning intellectually. To provide the learning material of the domain knowledge in many ITS, the learning materials are statically associated with each other in advance and given to student based on her/his understanding state. Motivating student and making them more interested in the learning content is the system's task in the computer-supported systems. If students study on content which they are interested in, learning activity becomes more effective. Our research objective is to construct a system which automatically generates multiple-choice cloze exercises from text input by the student. We focus on supporting individual study of learning English grammar. In this paper, we propose a representation method of English grammar by Part-Of-Speech (POS) tags and words, the calculation procedure for estimating the understanding state of student in the student model, and the learning strategy for generating the next exercise based on the student model.

1 Introduction

Knowing English became one of the most important and essential issues in everyone's life. It is necessary for many foreigners to develop themselves and advance their works. In order to learn English and check the effect, many people prepare for English examinations. People prefer to study English through computer by

Ayse Saliha Sunar · Yuki Hayashi · Toyohide Watanabe
Graduate School of Information Science, Nagoya University,
Furo-cho, Chikusa-ku, Nagoya, Japan
e-mail: {saliha,yhayashi,watanabe}@watanabe.ss.is.nagoya-u.ac.jp

Dai Inagi
Faculty of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Japan
e-mail: inagi@watanabe.ss.is.nagoya-u.ac.jp

T. Watanabe et al. (Eds.): Intelligent Interactive Multimedia: Systems & Services, SIST 14, pp. 289–298.
springerlink.com

themselves in recent years. Intelligent Tutoring System (ITS) is the research field which aims to support studies individually, using the Artificial Intelligence technology. ITS gives students an appropriate learning content from the domain according to their understanding [1]. Although ITS provides individual learning environments, the systems mostly give the student a part of the same learning content. In the domain knowledge, the learning content must be structured in such way that can be easily managed in order to adapt learning to student's understanding. However, constructing the domain of English is quite hard [2]. The biggest challenge on representing English is that English does not consist of particular formulae and theorem like mathematics. If English grammar is represented as formulae, it would be easy to manage the domain knowledge. Kyriakou et al. proposed a tool for managing domain knowledge and helping tutors in ITS [3]. Their system consists of three components: knowledge concepts which are organized in network, course units, and meta-description which is a data set of learning objects. This system describes not only a new metadata, but also its concept and relations. Although this system allows tutor to manage the domain by creating, storing, viewing, and editing the metadata or can create the concept network of domain, students still need manually to define relation links, contents and concepts by themselves, but not do automatically. Faulhaber et al. constructed the web-based learning system named ActiveMath for mathematics [4]. This system represents the learning content (rule/concept) as the nodes and Inter-node relations are dynamically extracted from the domain. Even if relations are dynamically determined, this system must also predefine a domain which is assigned to the difficulty level. However, if students study on content which they are interested in contrast to predefined learning content, the learning activity would be more effective and students would be more motivated to study.

In this research, we aim to construct an ITS which automatically generates multiple-choice cloze English grammar exercises from student's input text based on the understanding state of student. To automatically generate the English questions, MAGIC (Multiple-choice Automatic GeneratIon system for Cloze question) was composed in our laboratory which generates multiple-choice cloze question from an input English text [5]. The MAGIC system only generates an English question; it does not adapt to the learning system for learning English grammar. In this paper, we propose some mechanisms as for the estimation of student understanding, for exercise generation based on student model to add into the MAGIC. Since grammar consists of rules, we purpose to formulate English grammar rules. English grammar rules are formulated by Part-of-Speech (POS) tags and some words. Firstly, our system generates a few exercises from the student's input text. After the student answered the exercises, the understanding state of student is estimated in the student model based on the accuracy of the answers. Then, the next exercises are generated from the newly-input text based on the understanding state of the student. In this paper, we represent English grammar rules by POS tagger and words and then discuss the constructional formulation so as to be useful as our learning strategy. We also discuss how to estimate the understanding state of student and generate the next exercises.

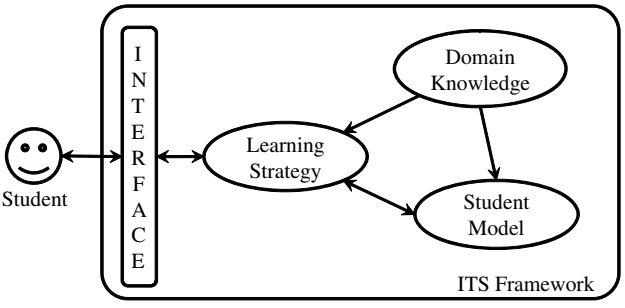

Fig. 1 Framework of ITS

2 Framework of Computer-Supported Learning System

ITS is a computer-supported learning system which consists of three main components: namely, domain knowledge, student model, and learning strategy as shown in Figure 1. Domain knowledge represents a learning content to study. ITS supports their learning activities by managing the understanding states of students in the student model. The student model manages learning records of the student, the learning progress, and the understanding states derived correspondingly from the domain knowledge, and then the learning strategy module determines the next instructional actions with respect to the student's experiments [1].

The key idea of ITS is to dynamically provide a learning content which is appropriate for the student's understanding. If the domain knowledge is defined properly, ITS can accurately determine the understanding state of student. Also, the learning strategy is applied based on the student model. In other words, the learning strategy estimates the next content, which is defined in the domain knowledge, according to the understanding state of student. On the contrary, if the domain knowledge is defined insufficiently, system can neither estimate the understanding state of student in the student model nor generate an appropriate learning content for the student. If a system has these components, it can provide learning activity. Since MAGIC only generates the English multiple-choice cloze questions, some mechanisms are needed to modify MAGIC. In this research, the English grammar is defined in the domain knowledge. After the student inputs the text, the system puts the appropriate sentence in the domain knowledge. The student model is also inserted in MAGIC to enhance it. The model supports to estimate the understanding degree of student for each English grammar rule based on the student's answers. Then, the learning strategy determines the next multiple-choice cloze exercises based on the student model. If these main parts are constructed coherently, MAGIC can generate exercises which are appropriate for the student.

Figure 2 illustrates a framework of our system for learning English grammar. The student model, which is one of main components of ITS, should be added to determine the understanding state of student. In MAGIC, after inputting the text, the system attaches Penn Treebank II tags [6] to all words. Then, the system

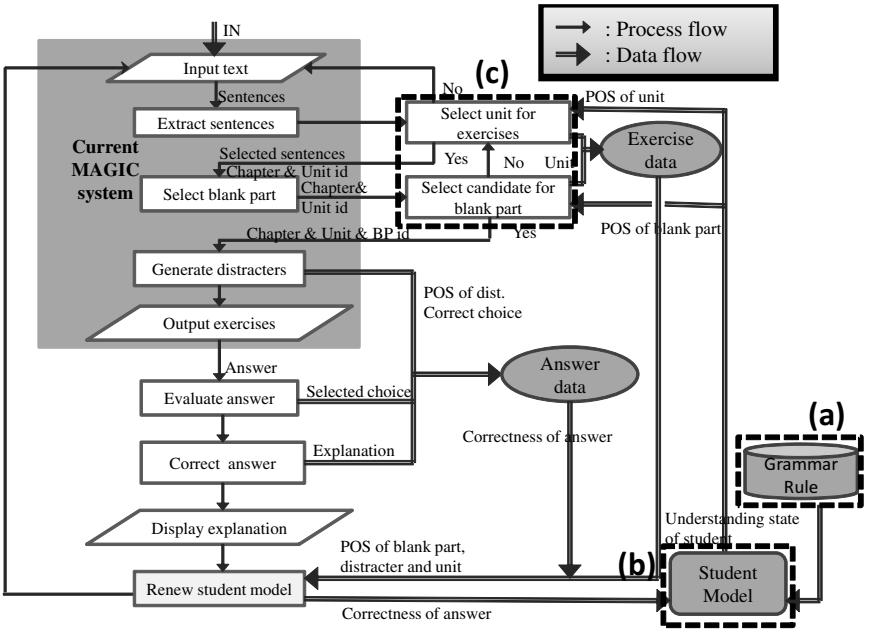

Fig. 2 Framework of our system

performs three procedures: extracting sentences from texts which are appropriate for multiple-choice cloze questions, determining blank part and generating distracters. The system uses some methods to carry out these processes. In the first process, Preference Learning is executed using words and POS tag information emerging in the existing multiple-choice cloze questions to put the input sentences in order. In order to make up this order, Ranking Voted Perceptron [7] is used. Ranking Voted Perceptron calculates ranks for each input sentence according to their similarity to the existing questions. As a result, the sentences which are appropriate to compose a cloze question for an examination like TOEIC are ranked. In the next processes, blank part and its distracters are estimated based on Conditional Random Field (CRF). In the current MAGIC system, CRF is introduced to attach labels to words of the sentence, and then a blank part is defined as the named entity in a sequence of words and represented by IOB2 format [8]. Sequences of words, POS tags and distracters with their named entities in the existing multiple-choice cloze questions are learned. The word which has the largest marginal probability of some particular tags is determined as a blank part. Its distracters are also determined based on result of CRF.

In order to generate exercises based on the understanding degree of student, it is needed to construct learning contents first. The domain knowledge which is shown in Fig. 2(a) represents English grammar rule as divided units. In order to estimate the understanding state of student for each unit, the student model is added in MAGIC as shown in Fig. 2(b). To generate exercises which are suitable for the student the

Table 1 Example of English grammar rule representation

Chapter	Passive Voice
Unit	General structure of passive sentences
Grammar rule	VB VBD by NP
Candidate(s) of blank part	"VBD" or "by"
Example sentences	The house **was built** in 1470 **by** somebody.

process of selecting blank part and generating distracters are altered. The learning strategy is applied based on the student model in Fig. 2(c). Blank part and its distracters, hereby, are to determine the student model to generate appropriate exercises. Then, the system outputs multiple exercises to the student. Finally, after the student answered the exercises, our system evaluates the student's answer and corrects the student's mistakes. Also, our system updates the student model according to the accuracy of the answers before generating the new exercises.

3 Grammar Structure

To construct a system for making English grammar learn, the domain knowledge of English grammar should be defined so as to be able to manage the student model and apply the learning strategy. We examined English textbooks to decide the structure of English grammar. In general, the English grammar is divided into chapters and units. Each chapter includes some units which are relevant to the chapter's subject. Each unit represents a single grammar rule. Since blank parts are selective part(s) of exercises to assess the student's knowledge of the grammar rules, we also examined blank parts of the exercises on the English textbooks.

Results of our investigation show that most of English grammar rules can be represented as the ordering of part-of-speech. In addition, some words might be important as much as their type (part-of-speech) and their placement in the sentence. In this research, we represent each English grammar rule by a composition of POS tags and words. We determine candidates of the blank part for the grammar rules while defining the grammar rules.

Table 1 shows an example for the representation of a grammar rule. The unit represents the basic rule in Passive Voice chapter. In this example, "*VB*" (base form of verb) and "*VBD*" (past form of verb) are word level of POS tags, "*by*" is the important word and "*NP*" (noun phrase) is the phrase level of POS tags. For instance, usage of past participate type of verb (*VBD*) and usage of preposition "*by*" are more characteristic parts in learning the *passive voice* than the other parts such as subject of the sentence. If the student answers these parts properly, our system can estimate that student has the knowledge of the *passive voice*.

4 Learning of English Grammar

4.1 Student Model

The student is supposed to understand a unit completely when s/he correctly answers most of exercises which are relevant to each defined blank part of the grammar rule in the unit. For estimating understanding state of the student of each unit, all answer information of each blank part of the grammar rule is used. Here, U is a set of all units, as shown in the expression (1). A set B_i indicates each determined blank part of the grammar rule i, and each exercise which is relevant to each blank part in the unit i is indicated in a set E_i, as shown in expressions (2) and (3), respectively. $f(e_{i,j,k})$ returns "1" if the student's answer of exercise k is correct. Otherwise, f returns "0". A number of correct answers for a blank part which belongs to the unit i are calculated by the function f. Based on the function, understanding state of unit i is calculated by the expression (5). d_i is a summation of rates of all correct answers per blank part. The formula is hereby defined over all defined blank parts of the unit.

$$U = \{u_i : \forall i \in [1,n] \text{ indicates unit ID}\} \tag{1}$$

$$B_i = \{b_{i,j} : \forall j \in [1,m] \text{ indicates determined blank part ID in unit } u_i\} \tag{2}$$

$$E_i = \{e_{i,j,k} : \forall k \text{ indicates exercise ID which belongs to } b_{i,j} \text{ in unit } u_i\} \tag{3}$$

$$f(e_{i,j,k}) = \begin{cases} 1 & (e_{i,j,k} \in E_i \text{ is correct}) \\ 0 & (otherwise) \end{cases} \tag{4}$$

$$d_i = \frac{1}{|B_i|} \sum_{b_{i,j} \in B_i} \frac{1}{|E_i|} \sum_k f(e_{i,j,k}) \tag{5}$$

After receiving the student's all answers, the system evaluates the correctness of the answers. Then, the system updates the understanding state of student based on the checked answers.

4.2 Learning Strategy

The learning strategy is applied to select an appropriate exercise based on the understanding state of student has been described in Section 4.1. While selecting rules and deciding blank part in the process of generating exercises, the learning strategy is considered as shown in Fig. 2. In order to select the unit which has the suitable grammar rule, extracted sentences are tagged by Penn Treebank II tags. If a sentence includes the ordering of the POS tag(s) and important word(s) which are defined for the grammar rule of the unit, we can say that the sentence has the grammar structure of the unit which represents the grammar rule. In order to decide which suitable grammar rules can be adapted to generate exercises from each sentence of input text, the grammar structure of the sentence and the grammar structure of the rule are compared. If the sentence includes the grammar rule, the sentence and the unit are matched. In this case, one or more units can be matched with one sentence. An exercise is generated from the sentence based on one of the grammar rule of the

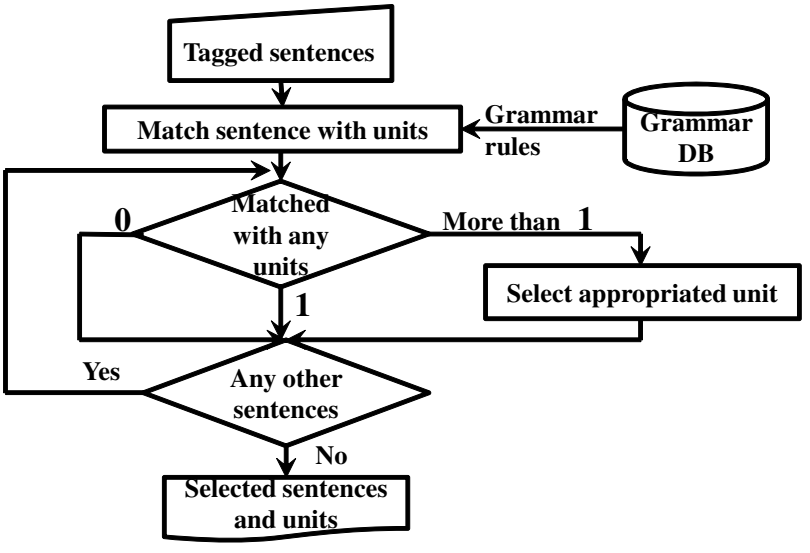

Fig. 3 Unit selection process

matched unit. Thus, the learning strategy is applied to choose the appropriate unit among the matched plural units to generate an exercise based on its grammar rule.

Figure 3 shows a flowchart for the selection process. If a sentence matches with none of the units, any exercise is not generated from this sentence. Then, the system carries out the process of matching for the other sentence of input text, if a sentence exists. If a sentence matches with only one unit, the exercise is generated from this sentence based on the grammar rule of this unit. If the sentence matches with more than one unit, one of them is selected to generate the exercise from the sentence based on the grammar rule of the selected unit. After the unit was selected, the system checks whether there is another sentence in the input text or not. If there is, the process of matching is preceded. The learning strategy is applied based on the understanding state of student to select the unit. In order to judge whether a student understands a unit or not, we introduce threshold α which determines the understanding state of the student for each unit. α ranges from 0 to 1 ($0 \leq \alpha \leq 1$). If d_i is larger than α , it is judged that the student understood the unit i. Otherwise, the system judges that s/he has not understood the unit i yet. In the selection process, the unit which is the easiest one to advance to threshold α is selected. If all of candidate units have already reached to α , the lowest one is selected.

After selecting the units, the placement of blank part is determined. In order to decide the appropriate blank part of an exercise, our system considers the blank part information of the matched grammar rule. In order to decide that a unit is completed successfully, each blank part of unit should be studied and completed successfully. Therefore, at least one exercise should be asked on each blank part. Thus, the percentage of correct answers per the blank part is also calculated. The blank part which has the lowest percentage is determined as a candidate for the blank part. Then, our

system checks if results of CRF are compatible with decided candidates for the blank part or not first. If the highest result of CRF is not one of candidates of blank part of the unit, the next highest result is checked to generate a sufficient exercise.

5 Example

In our system, a student can input a long-length or short-length English text. In this example, we assume that the student inputs one following sentence:

> *"If I were in your situation, I would ask to speak with the manager."*

First, this sentence is tagged by Penn Treebank II tags:

> *(TOP (S (SBAR (IN If) (S (NP (PRP I)) (VP (VBD were) (PP (IN in) (NP (PRP$ your) (NN situation)))))) (, ,) (NP (PRP I)) (VP (MD would) (VP (VB ask) (S (VP (TO to) (VP (VB speak) (PP (IN with) (NP (DT the) (NN manager)))))))) (. .))).*

Then, the system compares the grammar structure of the sentence to the structures of the defined grammar rules. Currently, 65 grammar rules have been defined. This sentence is matched with the unit 2-1 (unit 1 of chapter 2) and the unit 4-5 (unit 5 of chapter 4). The chapter 2 is on "Infinitive" which has the basic rule which is represented by "*TO VB*" and only one candidate for the blank part (*TO VB*); the chapter 4 is on "If Clauses" which has the rule which is represented by "*If NP VBD, NP MD VB*" and two candidates for the blank part (*VBD* or *MD VB*). These two units are shown as follows:

Chapter 2	Infinitive
Unit 1	General rule of infinitive
Grammar rule	TO VB
Candidate(s) of blank part	"TO VB"

Chapter 4	If Clauses
Unit 5	Usage past tense in if clauses
Grammar rule	If NP VBD, NP MD VB
Candidate(s) of blank part	"VBD" or "MD VB"

Since this sentence is matched with two units, the system should decide one of them to generate the exercise based on the student model. In this case, we set $\alpha = 0.6$. A number of exercises and student's correct answer is shown in Table 2.

Table 2 Number of the student's answers

	2-1	4-5	
	TO VB	VBD	MD VB
Number of correct answers	3	1	2
Number of all exercises	4	2	3
Percentage of correct answers	0.75	0.5	0.67

By using the expression (5), the understanding states of student for units d_{2-1} and d_{4-5} are calculated as shown in the expressions (6) and (7) respectively.

$$d_{2-1} = \frac{1}{1} \cdot \frac{3}{4} = 0.75 \tag{6}$$

$$d_{4-5} = \frac{1}{2} \cdot (\frac{1}{2} + \frac{2}{3}) = 0.58 \tag{7}$$

The exercise is generated from the grammar rule of the unit 4-5 according to the learning strategy while α is equal to 0.6, because the d_{4-5} is smaller than the threshold. After selecting the unit, our system estimates the blank part. Since the part of *VBD* has the higher result of CRF and the lower percentage of correct answers, the part of VBD is estimated as the blank part of the exercise. Then distracters are generated for the estimated blank part based on the CRF. Finally, the system outputs the exercise which was generated on the blank part (VBD) of the unit 4-5:

If I ( ) in your situation, I would ask to speak with the manager.

1. were (correct answer)
2. been
3. being
4. will be been

6 Conclusion

In this paper, we proposed a framework for the learning system which generates English multiple-choice cloze exercises from input text according to the understanding state of student. We purpose a way to represent knowledge of English grammar. It can be formulized by POS tags and words, because English grammar consists of grammar rules. All grammar rules are defined as individual unite. In order to select an appropriate one of the units which are matched with the structure of the input sentence, the learning strategy has been defined. Furthermore, the calculation method for estimating the understanding state of student in the student model for each unit is defined.

For our future work, we have to add new English grammar rules to the domain knowledge. We need to confirm that sentences and units can be matched correctly. In addition, rules are independently defined for this time. For estimating the understanding state of a student more accurately, the relation among grammar rules may need to be considered. In this paper, we focused on the process of generating exercises. We plan to consider a method for automatically providing explanations to correct their mistake after evaluating the answers of the student.

References

1. Corbett, A.T., Koedinger, K.R., Anderson, J.R.: Handbook of Human-Computer Interaction, pp. 849–874 (1997)
2. Heilman, M., Eskenazi, M.: Language Learning: Challenges for Intelligent Tutoring Systems. In: Proc. of the Workshop of Intelligent Tutoring Systems for Ill-Defined Domains, 8th International Conference on Intelligent Tutoring System, pp. 20–28 (2006)
3. Kyriakou, P., Hatzilygeroudis, I., Garofalakis, J.: A Tool for Managing Domain Knowledge and Helping Tutors in Intelligent Tutoring Systems. Journal of Universal Computer Science 16(19), 2841–2861 (2010)
4. Faulhaber, A., Melis, E.: An Efficient Student Model Based on Student Performance and Metadata. In: 18th European Conference on Artificial Intelligent (ECAI 2008). Frontiers in Artificial Intelligent and Applications (FAIA), vol. 178, pp. 276–280. IOS Press (2008)
5. Goto, T., Kojiri, T., Watanabe, T., Iwata, T., Yamada, T.: Automatic Generation System of Multiple-Choice Cloze Question and its Evaluation. KM and E-Learning: An International Journal 2(3), 210–224 (2010)
6. Tsuruoka, Y., Tsujii, J.: Bidirectional Inference with the Easiest-First Strategy for Tagging Sequence Data. In: Proc. of HLT/EMNLP 2005, pp. 467–474 (2005)
7. Collins, M., Duffy, N.: New Ranking Algorithms for Parsing and tagging: Kernels over Discrete Structures, and the Voted Perceptron. In: Proc. of 40th Annual Meeting of the Association for Computational Linguistics, pp. 263–270 (2007)
8. Sang, T.K., Veenstra, J.: Representing Text Chunks. In: Proc. of EACL 1999, pp. 173–179 (1999)