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An Intelligent Tutoring System for Teaching Thai as a Second Language

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Abstract

Intelligent Tutoring System is an attractive application of Artificial Intelligence in Education, especially in language teaching. This paper presents the preliminary results obtained from a research project aimed at developing Thai Tutor, *an intelligent tutoring system, which can assist students who are learning Thai as a second language. In this primary stage of the system's development, we concentrated on three broad areas: 1) a web-based application for system architecture; 2) basic Thai language usage; and 3) pronunciation and tonal skills necessary for beginners. Learning behavior, which results in the significant improvement of the speed and quality of students learning, will be addressed in subsequent studies of developing* Thai Tutor.

Keywords: intelligent language tutoring system, intelligent and individual feedback, web-based language instruction, language teaching

1. Introduction

Lecturing is a conventional way of teaching that is different from tutoring. While lecturers need to convey all the subject content as scheduled in the teaching plan, tutors, who normally accommodate only a small group of students, can follow the progress of each student and assign proper lessons and exercises as needed. Specifically, one-on-one human tutoring is widely accepted as a well-understood way of communicating knowledge. It allows learning to be highly individualized and consistently yields better outcomes than other methods of teaching [2]. However, the one-on-one tutoring is limited by the number of experienced tutors available and time that each tutor has.

Thus, the Intelligent Tutoring System (ITS) provides an attractive application of Artificial Intelligence in Education. It is a program capable of providing students with tutorial guidance in a given subject. The program mimics the way the one-on-one tutors conduct their classes. Lessons and practice are dynamically chosen according to the student's language proficiency and progress. A full fledged ITS: a) has specific domain expertise; b) is capable of modeling the student knowledge in order to discover the reason(s) of his mistakes; and c) is able to make teaching more effective by applying different tutorial strategies [6]. Records and updated histories of individual students are kept in *Student Model*. These details assist in choosing the next activity for that student. The evaluation process of the student, in order to designate the proper activity, is performed in the *Tutorial Module*. Using the expert system concept, the ITS stores the knowledge of how to teach the subject to students who have different background and performance. It allows the overall system to demonstrate or model a correct way of teaching the subject. Both the *Student Model* and *Tutorial Module* will refer to knowledge about ideal student actions in the expert system.

The ITS framework has been widely investigated in various areas such as mathematics [3], science [10] and second language learning [5]. Current computational linguistic research involves the intelligent tutor for teaching English [14], and German [8] as a second language. Thai language has been of interest to foreigners for a long time. Important evidence is the increase in the number of Thai study courses in many institutions. However, the experienced Thai language teachers who can conduct effective classes using English as the teaching tools are truly limited. Developing a *Thai Tutor* system, therefore, becomes a very useful task both for institutes as supplementary material, and foreigners wishing to learn Thai by self- studying.

In this paper, we propose the preliminary findings obtained from a research project aimed at developing *Thai Tutor* (TT), an intelligent tutoring system to assist students to learn Thai as a second language. We concentrated on basic Thai grammar, the system architecture, and learning behavior. The paper is organized into five sections. Section two describes the main characteristics of Thai language and focuses on the

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essentials for beginners in everyday usage. Section three introduces our web-based *Thai Tutor* architecture and mode of operations, including the *Tutorial Module* and Expert System which are domain dependent. Section four surveys the existing intelligent tutor systems in various applications including algebra, and different languages teaching. The final section concludes the paper and suggests areas for ongoing research.

2. Thai language characteristics

The Thai language has distinct differences from well-known Western languages like English, German, and French. English takes the verb-subject agreement to describe natural gender, tenses and subjunctive mood [6]. Cases have thus been replaced by prepositions and fixed word order while subtle meaning distinctions can be conveyed through a highly sophisticated use of tense expressions.

English considers gender according to its nature and some non-living objects are considered as male or female. For example, when we mention about a "ship", we refer to "she" for being a subject, and "her" for being an object. German discriminates words such as nouns, adjectives, and pronouns as being masculine, feminine, or neuter. In Thai, we do not consider non-living objects as having gender.

Besides using temporal adverb (e.g., yesterday, today, etc.), English concurrently transforms the verb form according to the tense the statement aims to express. For example, the sentence "Bob went to see the dentist yesterday." The verb "went" is the past tense form of the verb "go" which is converted corresponding to the adverb "yesterday". In Thai, all verbs have only their root form. There is no transformation according to tenses, gender of subjects, or subjective mood. The expression of different situation is done by adding to the sentence different words which have the desired meaning.

Even though Thai language is simple regarding verb aspects, the difficulties in learning Thai language to most learners involve pronunciation and tones. Words with the same phonetics can have different meaning by changing tones. There are up to five possible tones for each Thai word. Some phonetics can be only three tones while some can be five tones depending on the main characters sound forming the words. Pronouncing the wrong tone or different tone is regarded as wrong meaning. Moreover, occasionally some tones do not have any specific meaning. For example, the phonetic "mai" with a unique spelling in Thai writing has three different tones: low, medium and high. The meanings are "silk", "new" and "burn", respectively.

Since the *Thai Tutor* system we are developing is for beginners, we decided to initially teach alphabets and constituted words that are often used in everyday life. The lessons emphasize the pronunciation of simple, useful words and sentences, and aim for constructing speaking and listening skill.

Section three begins with some fundamental ideas of a generic intelligent tutoring system, followed by the development of our *Thai Tutor* architecture which is a web-based application. The functions of *Student Model* are finally discussed.

3. System architecture

3.1 A generic intelligent tutoring system

The development of ITS for education has been investigated for a few decades. Most efforts attempt to capture methods of teaching and learning exemplified by a one-on-one tutorial approach. This tutoring method is widely accepted both by the educational community and culture [11]. Even though ITS can be implemented in a variety of ways, most have the same structural characteristics as shown in Figure 1.

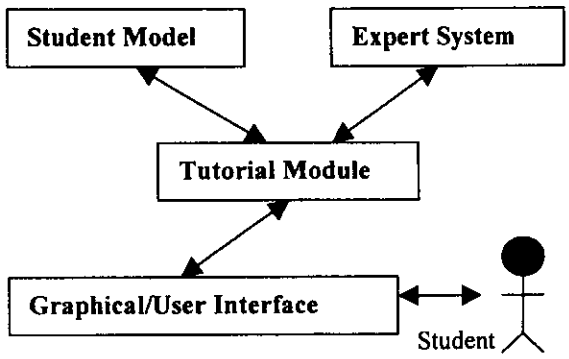

Figure. 1. Generic intelligent tutoring system

The system comprises a tutorial component, a *Student Model* for keeping track of student progress, a cognitive simulation of an expert problem solver, and the code underlying the user interface [1]. The heart of an ITS is its expert system. The expert system embeds knowledge to provide ideal answers to questions. It explains not only final results but each of the smaller, intermediate reasoning steps. More obvious examples are in the systems for teaching mathematics when one problem can generate many different answer paths and elaborate problem solving steps [11].

In *Proceedings of the Third International Symposium on Communications and Information Technologies 2003*, Prince of Songkla University, Thailand, pp.10 – 14.

3.2 The Web-Based *Thai Tutor* System

As web technologies for adapting existing educational content converge with increased bandwidth, web-based tutoring systems with integrated multimedia are more and more expected to have greater profound degrees of adaptivity and interactivity [8]. The diversity of users presents a challenge in system design. First of all, the system needs to be general enough to suit a variety of competencies, and backgrounds. For example, when analyzing the mistakes from doing exercises, the intelligent language tutor at least has to do it based on the native language of the student [15]. An online system must adopt a more general scheme in order to accommodate international access and cases where the native language of the user might not be known. However, system performance and efficiency are also an important issue. A visible delay between the browser and the servers defeats the purpose of an interaction system, and can distract from problem solving activity [4]. The *Thai Tutor* we are developing resides on a Linux machine and uses English as the communication tool.

Displaying Thai characters is a big issue when implementing a digital Thai system. German and French, for example, employ English characters and some special symbols in writing, but this is not the case in Thai. Chinese writings, like Thai in some respect, also have their own characters instead of using English to describe the languages. However, writing Thai is more complicated than others. With one Thai character, there can be totally up to three levels of symbols which locate above and below it. Therefore, to provide the international access without any modification to the client side, we store Thai words as image files. In this case, the system performance will be acceptable as the major display will be English along with other adaptive multimedia files, such as sound and animation.

An architecture of the *Thai Tutor* is then evolved from the stand alone general tutoring system above, and shown in Figure 2.

3.3 *Student Model* and Expert System

In the literature, a number of student modeling techniques have been employed for ITS. The *Student Model* functions as an accumulative and adaptive database for each user. Therefore, a challenging task in implementing multi-user system is to identify users while maintaining user models adaptive to the individual. A number of solutions have been proposed which range from cookies [13], structured URLs [4], and hidden fields to login screens [15]. Deciding on an appropriate alternative depends primarily on the purpose of the application.

Our *Thai Tutor* system adopts the *German Tutor* technique [8]. The system stores a database of users, each entry established by an initial login. The student login and password are used to identify a user. This is sufficient since students do not navigate through different HTML pages during learning, but can access a consistent applet. *Student Model* requires the user identification for two main functions: a) to store scores across a number of error types, or nodes, such as pronunciation, vocabulary, punctuation, etc. Each node is broken down into more fine-grained categories. Dealing with pronunciation learning, the error will be categorized into various word tones of low, medium, and high sound characters. For example, a medium sound character when forming a word can have five tones. Thus, the student error can be finely recognized as a unique tone to the medium sound word. This information is shown to the user at the end of each exercise set; b) to keep and update history of the learners. Depending on student input, the score for each node will go up or down. These data will be used to adjust the lesson, emphasis of an exercise, etc. These two

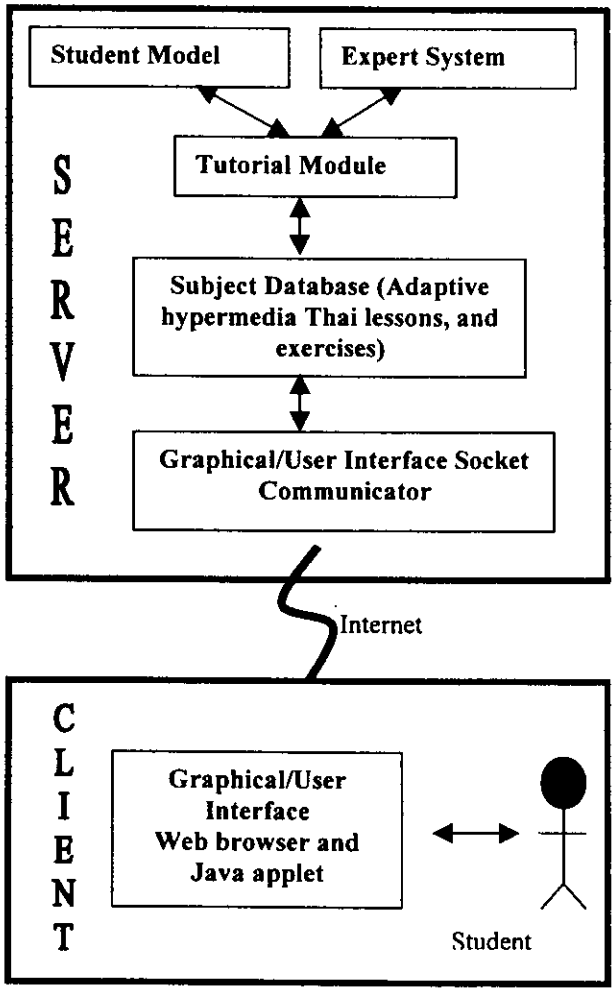

Figure 2. Web-based Thai tutoring system

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functions together allow the system to perform a fine-tuned assessment of student competency. Thus a single-error will not drastically change the student's overall assessment. Furthermore, the student can be recorded as making a high tone error for medium sound words, not high tones of all words. Consequently, the system will focus on high tones of specific sounds. This subtlety of evaluation is desirable in a language teaching environment because, as the student progresses through a language course, a single measure is not sufficient to capture the knowledge attained or to distinguish among learners.

Foreign language teaching also has to focus on the learners' native language especially when pronunciation is emphasized. Experts in teaching a second language all realize that different native speakers have different difficulties in correctly pronouncing some sounds in another language. Our *Thai Tutor* keeps the information about students' first language in the *Student Model*. Then we use this information to map a proper model of the ideal student stored in the expert system. This results in the initiation of a teaching scheme for individual students. However, this teaching pattern can be dynamically adapted according to the learner's performance.

4. Related works

ITSs have been developed in various areas such as mathematics, science, and languages. McArthur, et al., 2000 presented an ITS called *Mathematical Microworlds* [11]. This system allows students to create different kinds of mathematical objects (e.g., polygons) that have different properties or features. The students then can inquire to find and understand the relationship patterns between those objects' properties. The system also provides various tools in presenting and manipulating objects with multiple mathematics perspectives. However, this system is not a web-based application.

The algebra tutor called *AlgeBrain* is put forth by Alpert, et al., 1999 [1]. The development started from building a stand- alone tutor. Then they converted it to one that is capable of operating over the World Wide Web. This study gave the idea of gathering information for all users in the *Student Model* on the centralized server. As a result, students can continue the learning process with their own academic history wherever they are.

In the conventional ITS, the tutor's role is to monitor and manage an individual's trajectory through a curriculum and provide feedback on individual problem solving actions via the Internet. Singley, et al., 2000 introduced the notion of a *Team Tutor* to a system called *Algebra Jam* [12]. It provides an opportunity for a team of students to learn algebra in a collaborative way. The team works together to solve extended, distributed, and multi-step problems. This effort creates social interaction and builds a community of learners.

In additional, several studies have focused on different aspects of Intelligent Language Tutoring Systems (ILTS) for English as a second language. Fum, et al., 1989 concentrated on generating, in a cognitively transparent way, the right tense for the verb(s) appearing in exercises presented to students [6]. Another work focusing on English verb usage was proposed by Fum, et al., 1992 for teaching English to Italian students [7]. This paper investigated the relationships between naïve grammar (knowledge derived from textbooks and school grammars), and formal grammar (developed by theoretical and computational linguists). Another intelligent English language tutoring system, called *Tutor Assistant*, is designed to be an authoring tool for instructors to create their own lessons and exercises [14]. This study also evaluated the degree to which instructors can author good quality content for an *English Tutor* and established benchmarks for development times.

ALICE is a language training environment for learning Japanese [9]. It uses Natural Language Processing (NLP) as a basis both for assisting instructors in preparing exercises and for evaluating student responses. Finally, a *German Tutor* was developed by Heift and Nicholson, 2000 [8]. This attempted to implement generality, interactivity and modularity into the system with an emphasis on efficient and adaptive hypermedia.

As for the Thai learning system, there are several Thai courseware either on a stand-alone machine, or publicly on the Internet. However, they are conventional Computer Assisted Instruction (CAI) setups.

5. Conclusion and ongoing research

This paper presented a preliminary study of the *Thai Tutor* system for second-language learners. At this stage, we focused on the system architecture which is a web-based application, lessons on basic Thai grammar usage, and the essential skills of pronunciation, and tones necessary for clarity in communication.

Our ongoing research extends the capability of the system to handle the temporal information when tenses are involved. Although verbs in Thai sentences are not modified according to the chronological order of events, they need some additional words (e.g., adverb) to determine the tenses. Therefore, representation and reasoning about temporal knowledge are essential to this issue. The long-term project for a fruitful *Thai Tutor* requires developing the ability to recognize and diagnose learners' sounds when speaking skills are emphasized. Unfortunately, current technology does not yet practically support this requirement.

In *Proceedings of the Third International Symposium on Communications and Information Technologies 2003*, Prince of Songkla University, Thailand, pp.10 – 14.

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In *Proceedings of the Third International Symposium on Communications and Information Technologies 2003*, Prince of Songkla University, Thailand, pp.10 – 14.

Developing an Intelligent Web-Based Thai Tutor: Some Issues in the Temporal Expert

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Abstract

Computer aided language learning system is an attractive application of Artificial Intelligence in Education. This paper presents details of a web-based Thai language tutoring system. The system, called Thai Tutor (TT), assists students who are learning Thai as a second language. Since temporal information constitutes an important part to the meaning of a sentence, we concentrate on a module of the system called the temporal expert. This domain dependent expert is devoted to represent and reason the temporal knowledge by using Allen's interval-based temporal logic. The temporal expert provides information about the order of events so as to convey the intended meaning of the sentence.

Keywords: intelligent language tutoring system, web-based language instruction, temporal reasoning

1. Introduction

Capability in language learning is individual. This may depend on his/her first language, culture, talent, and teaching environment. Effective learning method needs a self-controlled system that allows students to practice and revise the lessons on demand. Classical lecture conveys all subjects' contents as scheduled in the teaching plan. In contrast, tutors, who normally accommodate only a small group of students, can follow the progress of each student through assignments and revision exercises as needed. Specifically, one-to-one human tutoring is widely accepted as a well-understood way of communicating knowledge. It allows learning to be highly individualized and consistently yields better outcomes than other methods of teaching [2]. However, one-to-one tutoring is limited by the number of qualified tutors as well as their availability.

An intelligent tutoring system (ITS) is a program capable of providing students with tutorial guidance in a given subject. The program mimics the way one-to-one tutors conduct their classes. Lessons and practices are dynamically chosen according to the student's language proficiency and progress. A full fledged ITS: a) has specific domain expertise; b) is capable of modeling the student's knowledge in order to discover the reason(s) of his mistakes; and c) is able to make teaching more effective by applying different tutorial strategies [4]. Records and updated histories of individual students are kept in *Student Model*. These details assist in the determination of the next activity for that student. The evaluation process of the student, in order to designate the proper activity, is performed in the *Tutorial Module*. Using the expert system concept, the ITS stores the various teaching methodologies on how to convey subject knowledge to students with diverse background and ability. It allows the overall system to demonstrate or model a correct way of teaching the subject. Both the *Student Model* and *Tutorial Module* will refer to knowledge about ideal student actions in the expert system.

Our preliminary paper proposed in [12] investigates the *Thai Tutor* (TT) system architecture, various learning behavior, and basic Thai lessons structure. Here, we extend the system's ability to train students about tenses by using Allen's interval-based temporal logic.

2. Characteristics of Thai language

2.1 Sentence structure

Thai grammar refers mostly to word order and the use of words like "*dai*" and "*laeo*", so called *function words*. These words have basic meanings related to time and action, which alter tenses or give phrases and sentences different shades of meaning. Verbs in Thai sentences consist only their root form. There is no transformation according to tenses, number, gender of subjects, or subjective mood. The expression of different situation is done by adding to the sentence different wordings with the desired meaning.

In *Proceedings of the Workshop on Applications, Products and Services of Web-based Support Systems*, 2003. IEEE/WIC International Conference on Web Intelligence, Halifax, Canada. pp. 49 – 53.

Thai words are often interchangeable as parts of speech. Moreover, some of the words in a sentence may be optional. All Thai sentences have a complete form, where words may be omitted depending on the context and the formality of the situation [7]. In general, the more wordings a sentence has, the more formal it sounds. This interchangeability and flexibility of the language increase learning difficulties, especially to learners who are more familiar with languages where tenses are intentional.

2.2 Expression of temporal information in Thai

An important part of a sentence meaning is constituted by temporal information. The information implied by tenses indicates the order of events or situations. An event can be either time interval or instance of time in which the situation described in the sentence takes place and the moment in which the sentence is uttered. The relationship between events described the series of events constituting a scenario. Even though, verbs in Thai sentences are not modified according to tenses as mentioned earlier, using proper functional words or adverbs of time are essential for communicating the right meaning. For example, consider the sentence "I bought some food when I went to the market." The action "I bought some food" happened sometime when I was at the market. In Thai, we can express this two-clause sentence as:

ฉันซื้ออาหาร*ขณะที่*ฉัน*ไป*ตลาด or
ฉันซื้ออาหาร*ตอนที่*ฉัน*ไป*ตลาด

The *italic* words indicate verbs of each clause, while the **bold** words specify the conjunctions having the same meaning "while".

However, consider

ฉันซื้ออาหาร**หลังจากที่**ฉัน*ไป*ตลาด

By changing the conjunction, the meaning is changed to "I bought some food after I went to the market", in other words, the first clause happened after the second. Note that the verbs in each clause for all the sentences remain the same (no modification according to tenses). Each sentence uses the bold wording to specify the tense and order of the clauses.

3. System architecture

3.1 The web-based *Thai Tutor* system

As web technologies for adapting existing educational content converge with increased bandwidth, web-based ITSs with integrated multimedia are increasingly expected to have higher degrees of adaptiveness and interactivity [6]. The diversity of users presents a challenge in system design. It needs to be general enough to suit a variety of competencies, and backgrounds. For example, when analyzing the mistakes from completed assignments, the intelligent language tutor has to do it based on the native language of the student [13] at least. An online system must adopt a more generic scheme in order to accommodate international access and cases where the native language of the user might not be known. However, system performance and efficiency are also an important issue. A visible delay between the browser and the servers defeats the purpose of an interactive system, and can distract the problem solving activity [3]. The *Thai Tutor* we are developing resides on a Linux machine and uses English as the communication tool.

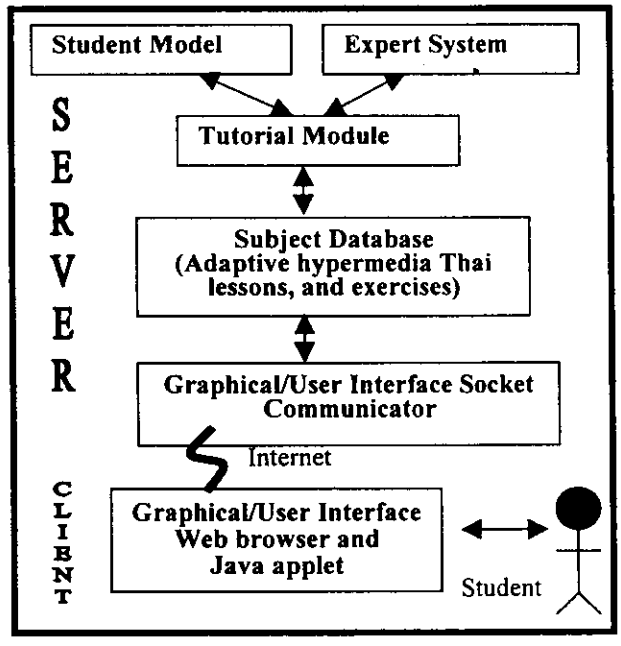

Figure 2. Web-based Thai tutoring system

Displaying Thai characters is a big issue when implementing a digital system. German and French, for example, employ English alphabets and some special symbols in writing, but this is not the case in Thai. Chinese writings, like Thai in some aspects, also have their own characters instead of using English alphabets to describe the languages. However, writing Thai is more complicated as compared to others. With one Thai character, there can be three levels of symbols located above and below it. Therefore, to provide the international access without any modification on the client side, Thai words are stored as image files. In this case, the system performance will be acceptable as the major display will be in English along with other adaptive multimedia files, such as sound and animation. Architecture of the *Thai Tutor* is then shown in Figure 2.

In *Proceedings of the Workshop on Applications, Products and Services of Web-based Support Systems,* 2003. IEEE/WIC International Conference on Web Intelligence, Halifax, Canada. pp. 49 – 53.

3.2 *Student Model*

In the literature, a number of student modeling techniques have been employed for ITS. The *Student Model* functions as an accumulative and adaptive database for each user. Therefore, a challenging task in implementing multi-user system is to identify users while maintaining user models adaptable to the individual. A number of solutions have been proposed which range from cookies [10], structured URLs [3], and hidden fields to login screens [13]. Deciding on an appropriate alternative depends primarily on the purpose of the application.

Our *Thai Tutor* system stores a database of users, each entry established by an initial login. The student login and password are used to identify a user. This is sufficient since students do not navigate through different HTML pages during learning, but can access a consistent applet. *Student Model* requires the user's identification for two main functions: a) to store scores across a number of error types, or nodes, such as pronunciation, vocabulary, punctuation, etc. Each node is broken down into more fine-grained categories. Dealing with pronunciation learning, the error will be categorized into various word tones of low, medium, and high sound characters. For example, a medium sound consonant when forming a word can have five tones. Thus, the student's error can be finely recognized as a unique tone to the medium sound word. This information is shown to the user at the end of each exercise set; b) to keep and update history of the learners. Depending on student's input, the score for each node will go up or down. These data will be used to adjust the lesson, emphasis of an exercise, etc. These two functions together allow the system to perform a fine-tuned assessment of student competency. Thus a single-error will not drastically change the student's overall assessment.

4. Temporal expert

4.1 Knowledge representation

Our Thai tutor needs an ability to generate and exercise the correct tense for each sentence. Since there is no tense transformation to the verb, TT system concentrates only on how to choose the appropriate function words, adverbs of time, and conjunctions, and also the degree of politeness. Based on Allen's temporal knowledge representation paradigm [1], we consider each primitive event as an interval of time. While a time interval can be an event, an activity or a situation.

The representation of a sentence starts with the sentence structure, which may consist of one or more clauses. The task to be solved is indicated in "Part_to_solve", e.g., finding proper function words, adverbs of time, and conjunctions. Information about each clause is schematically represented by a number of attributes that are:

- *Clause_type*: role of the clause i.e., main, co-ordinate, or subordinate clause;
- *Clause_form*: intention of the clause i.e., narration, question, negation, request, demand;
- *Relation*: a set of sub-attributes (a related interval, possible relation 1, possible relation 2, ..., possible relation *n*);
- *Formality*: degree of formality to which situation the clause applies.

A possible relation between two intervals is a disjunction of the thirteen primitive relations proposed by Allen [1]. They are before (*b*), equal (*e*), meet (*m*), overlap (*o*), during (*d*), start (*s*), finish (*f*), and their inverses which indicate by an "*i*" after the relation. These relations can be graphically shown in Table 1. The disjunction of these primitive relations expressively represents ambiguity between two events when the starting and finishing points of the events cannot be clearly stated.

Relation	Symbol	Symbol for Inverse	Pictorial Example
X before Y	b	a	XXX YYY
X equal Y	e	e	XXX YYY
X meets Y	m	mi	XXXYYY
X overlaps Y	o	oi	XXX YYY
X during Y	d	di	XXX YYYYYY
X starts Y	s	si	XXX YYYYY
X finishes Y	f	fi	XXX YYYYY

Table 1. Allen's thirteen interval relations.

4.2 Temporal reasoning

In this subsection, we introduce two examples of temporal reasoning in Thai tutor. The first example shows a simple sentence when the relation between two clauses implies the proper conjunction. The second example introduces the reasoning process when there is ambiguity between three events.

Example 1: Suppose the system proposes an exercise to students in order to find a proper conjunction indicating the order of two events ("I bought some food" and "I went to the market") as follows:

ฉันซื้ออาหาร ...(conjunction)... ฉันไปตลาด

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Here the meaning we intend to train students is "I bought some food when I went to the market". The schematic description of this sentence is the following:

Sentence: S1
  Structure: C1, C2
  Part_to_solve: conjunction
Clause: C1
  Clause_type: main
  Clause_form: narrative
  Relation: (C2, *s, f, d, e*)
  Formality: 2
  Part_to_solve: none
Clause: C2
  Clause_type: subordinate
  Clause_form: narrative
  Relation: (C1, *si, fi, di, e*)
  Formality: 2
  Part_to_solve: none

Typically, a Thai sentence can be applied with more than one function word to make the sentence sound more formal and polite. This depends on the context of the sentence. Here we represent the degree of formality as an integer in order to demonstrate the natural conversation. From the intended meaning of sentence S1, we can imply that

- The starting of the interval C1 ("I bought some food") was during the time period when the clause C2 ("I went to the market") was carrying on;
- The event C1 terminated before the ending of the event C2.

Therefore, the clause "I bought some food" could start, finish, during, or happen at the same time (equal) as the clause "I went to the market". When TT verifies the answer from learners, the temporal expert matches the relation between two clauses with a conjunction table to obtain the proper conjunction.

This exercise can be simply resolved by table look up techniques. However, the significant part of this task is the construction of the table. Each entry of the table contains a Thai word (e.g., conjunctions, function words, adverbs of time, etc.) that matches the corresponding situation (e.g., tense, formality, etc.). ■

In real situation, a conversation may refer to more than two events. In such cases, the temporal relationship between any pair of events may be unknown. In some cases, the system may have complete information about how the events could be related. But when new temporal information is entered, all relations will have to be revised to maintain the consistent knowledge of the overall scenario. To generate or verify an appropriate tense for a given clause or sentence, we need a reasoning process that infers the unknown relations or eliminates the inapplicable relations.

Example 2: Suppose we further know that "A friend came to my house after I left home for the market". This knowledge helps us to infer the relationship between the events "A friend came to my house" and "I went to the market" as the disjunction of relations "after (*a*)", "met by (*mi*)", "overlapped by (*oi*)", "during (*d*)", and "finish (*f*)". However, the temporal relation between events "I bought some food" and "A friend came to my house" remains unknown. The schematic representation of the additional knowledge can be shown as follows:

Sentence: S2
  Structure: C3, C2
  Part_to_solve: none
Clause: C3
  Clause_type: main
  Clause_form: narrative
  Relation: (C2, *a, mi, oi, d, f*)
  Formality: 2
  Part_to_solve: none
Clause: C2
  Clause_type: subordinate
  Clause_form: narrative
  Relation: (C3, *b, m, o, di, fi*)
  Formality: 2
  Part_to_solve: none

The reasoning task here is to generate the unknown relation between clause C1 and C3. The new fact (the relation between C3 and C2) adds a constraint about how the two events could be related. This may in turn introduce new constraints between other events. In this scenario, there are only three events and the relation between C1 and C3 is not predefined. The consequence of the added knowledge will identify the relation between C1 and C3. To achieve the task, we adopted Allen's temporal reasoning algorithm called *Constraints (R1, R2)*, where *R1* is the disjunctive relation between clauses C1 and C2, and *R2* is the disjunctive relation between clauses C2 and C3. This algorithm was later modified to the so-called Path Consistency algorithm [8].

```
Constraints (R1, R2)
    C ← ξ
    For each r1 in R1
        For each r2 in R2
            C ← C ∪ T (r1, r2)
    Return C
```

U is the mathematical union operation. T(*r1, r2*) is the transitivity function describing the inferred relations from primitive relation *r1* to *r2*. For instance, if interval *i* is during interval *j*, and the fact that interval *j* happens before interval *k* is added, then the transitivity function infers that interval *i* must be before interval *k*.

In our scenario, *R1* is the set {*s, f, d, e*} and *R2* is the set {*b, m, o, di, fi*}. After the reasoning process, the relation between clauses C1 and C3 may be any of the possible thirteen relations. Therefore, we cannot strictly

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specify the order of the two events (C1 and C3). In other words, all conjunctions are possible to conjugate the clauses. Until more new knowledge about temporal relation is provided, relation between the intervals can be further restricted. ■

5. Related works

Several ITSs for teaching languages have been proposed. A system for teaching English as a second language presented by Fum, et al., concentrated on generating in a cognitively transparent way, the right tense for the verb(s) appearing in exercises [4]. A related work by Fum, et al., [5] focused on the relationships between naive grammar (knowledge derived from textbooks and school grammars), and formal grammar (developed by theoretical and computational linguists). Another ITS, called *Tutor Assistant*, is designed to be an authoring tool for English language instructors to create their own lessons and exercises [11]. This study also evaluated the degree to which instructors can author good quality content for an *English Tutor* and established benchmarks for development times. ALICE uses Natural Language Processing (NLP) as a basis both for assisting instructors in preparing exercises and for evaluating student responses [9]. Finally, a *German Tutor* was developed by Heift and Nicholson [6]. This attempted to implement generality, interactivity and modularity into the system with an emphasis on efficient and adaptive hypermedia.

As for the Thai learning system, there are several Thai courseware either on a stand-alone machine, or publicly on the Internet. However, they are conventional Computer Assisted Instruction (CAI) setups.

6. Conclusion and ongoing research

Verbs in Thai sentences are not modified according to the chronological order of events. They need additional words (e.g., adverb of time, function words, conjunctions, etc.) to express the tenses. This paper presented a web-based ITS for teaching Thai as a second language, called *Thai Tutor*. The system is able to handle the temporal information when tenses are involved. A module, called *Temporal Expert*, is devoted to represent and reason the temporal knowledge by using Allen's interval-based temporal logic. The temporal expert provides information about the order of events so as to convey the intended meaning of the sentence. The long-term project for a fruitful *Thai Tutor* requires developing the ability to recognize and diagnose learners' pronunciation when speeches are emphasized. Unfortunately, current technology does not yet practically support this requirement.

7. References

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