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Modelling the Student to Individualise Tutoring in a Web-Based ICALL

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Abstract. In this paper we describe the techniques used for student modelling in an adaptive Web-based Intelligent Computer Assisted Language Learning (ICALL) system. The system teaches the domain of the passive voice of the English language and is called Web Passive Voice Tutor (Web-PVT). It dynamically models a student's progress in learning and is able to provide individualised tutoring and advice tailored to a student's knowledge level and individual weaknesses. The initialisation of the student model is based on a multi-dimensional stereotype approach. However, after the individual student has interacted with the system sufficiently, the initial values provided by the stereotype are overwritten to reflect the individual student. This allows the system to adapt to each particular student.

Keywords: Intelligent Computer Assisted Language Learning, Web-based Education, Student Modelling, Stereotypes, Adaptive Instruction.

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1. Introduction

Recently, in the field of computer-assisted learning, a lot of research energy has been put on Web-based instruction. Web-based educational systems offer platform independence of the application and easy access to it. Furthermore, students can access Web-enabled tutors from any location and at any time. These advantages ensure that the audience of web-based applications may be very large. This is even more the case for Web-based Computer Assisted Language Learning (CALL) systems, since the domain of language learning could benefit a lot from the means of Web-based technology. Indeed, when a language is being taught through the Internet then the potential audience may be internationally spread to a larger extent than it would be for other domains. The reason for this is that the potential students may be attracted to the system based on their interest in learning the language being taught irrespective of what their mother tongue is. This is not the case for other domains (e.g. history, physics, etc.) where the language used in the Web-based educational software poses a restriction to the potential international users who may not speak this language.

However, most learning systems and electronic textbooks accessible via the WWW up to now, lack the capabilities of individualised help and adapted learning support that are the emergent features of on-site intelligent tutoring systems (Weber and Specht 1997). A solution to this problem is the integration of the technology of Intelligent Tutoring Systems (ITS) with Web-based instruction, to render tutoring over the Web adaptive to individual students. This challenging goal forced in the recent years a number of research groups to engage in research on adaptive Web-based educational systems.

Adapting instruction and feedback to an individual student requires the system to be able to draw inferences about the student’s knowledge level and misconceptions. Furthermore, the system should
also draw inferences about certain other attributes of the student that may play a significant role in
students’ performance to exercises and/or way of learning. Such inferences may be drawn based on
observations of the student’s behaviour while s/he is interacting with the CALL system. For example if
s/he is careful or careless while solving exercises, whether the student needs more time than average in
order to master a concept, etc. Finally, the student’s prior knowledge of other languages (such as her/his
mother tongue) may provide additional information to CALL systems about the student’s proneness to
commit certain mistakes. All of the above pieces of information may be recorded in the student model.

The student modelling component is responsible for dynamically representing the emerging
knowledge and skills of the student (Nwana 1991) and for inferring the learner's knowledge and
misconceptions from her/his behaviour (Dillenbourg and Self 1992). Ideally, the student model will
comprise all those aspects of the student’s behaviour and knowledge that have possible repercussions
on her/his progress in learning. However, while trying to identify the student’s mastery of concepts and
misconceptions there are cases where an ambiguity may arise. In such cases it is quite important to use
information about the student’s prior knowledge and/or misconceptions rather than be restricted to the
information provided by the current session of interaction.

This paper describes the student modelling component of Web-PVT, which is a Web-based
Intelligent Computer Assisted Language Learning (ICALL) system. Web-PVT aims at teaching English
as a foreign language by providing individualised tutoring to each student. For this purpose it constructs
and maintains student models, which are both long term and short term (Rich 1979; 1983). The short
term student model is responsible for diagnosing possible errors of students while they solve exercises.
The system is based on the stereotype and the overlay technique to construct and update the long term
student model. The emphasis on the student modelling component of Web-PVT has been put on the bi-
directional interaction of two sub-components: the set of stereotypes that the student belongs to and the
individual student model that is inferred based on direct observations of the student’s behaviour.

2. Related Work

2.1 Web-Based ICALL Systems

There are not yet many ICALL systems that operate over the Web. One Web-based ICALL system
to practice grammar in an introductory course for German is the German Tutor (Heift and Nicholson
2001). The system constructs and maintains a student model by keeping a score about each grammatical
skill as well as the student's proneness to commit each one of a set of predefined categories of error.
However, there is no method for the initialisation of the student model. Therefore, in order to tailor the
feedback to errors to the individual student, the system has to observe the student’s problem solving
performance for some time. In the case of Web-PVT, the system uses the default assumptions of the
stereotype that the student is initially classified into in order to infer the knowledge level of the student
for each grammatical skill. Moreover, in order to update the student model, apart from using the
student’s ability to solve exercises that evaluate a certain concept, Web-PVT also uses information from
observation of her/his actions while navigating the structured theory hyperdocument (e.g. whether s/he
has visited a link). Finally, the German Tutor uses the information recorded into the student model to
display instructional feedback suited to the learner's expertise and to suggest remedial exercises.
However, the German Tutor does not provide any adaptive navigation support to students. In Web-PVT
on the other hand, the student model is utilised both to adapt instructional feedback and to provide
adaptive support to students while they navigate through the course material.

Another Web-based language tutoring system has been developed by Cristea, Okamoto and Cristea
(2000). The system is called MyEnglishTeacher and is aimed at teaching academic English. MyEnglishTeacher gradually builds an individual student model containing information concerning the
student’s interaction performance. Such information includes the last page accessed by the student,
grades of all the tests the student has taken, mistakes of the student and their frequencies, etc. The
individual student model is utilized in order to generate the “next learning steps” and the “review
suggestions”. The latter contains suggestions for consulting lessons and texts, which are connected to
errors that appeared in the student’s performance on tests posed by the system. The domain knowledge
of MyEnglishTeacher consists of a set of concepts organized in a linear hierarchy based on their
difficulty level. The system does not allow students to pass any level without taking the respective test
that evaluates this concept. In Web-PVT, the student apart from being able to select the “next most appropriate” topic to read or exercise to solve, s/he may also explicitly choose the specific topic that s/he wants to study.

Yang and Akahori (1997) have developed a CALL system that is delivered via the WWW, which is aimed at teaching the passive voice of the Japanese language. This system, similarly with Web-PVT allows the student to enter free text while solving exercises. The emphasis of the Japanese passive voice tutor is put on the use of powerful natural language processing techniques to analyse the students’ answers and perform error diagnosis. However, the system does not keep a record of each student to tailor feedback and advice to the particular weaknesses of that student. Furthermore, when performing error diagnosis and advice generation, the Japanese passive voice tutor does not deal with the problem of ambiguity resolution. In particular, when the answer of the student is passed to the error analyser, the system based on natural language processing techniques checks the answer of the student. If the answer is erroneous, the error analyser sends an error code to the advice generator. The advice generator, based on the error code it received, presents the student with the advisory message that corresponds to this particular code. In Web-PVT on the other hand, one particular mistake may have more than one explanation. In order to decide which explanation to present to the student, Web-PVT consults the long term student model.

2.2 User Modelling via Stereotypes

Stereotypes have been widely used in the field of user modelling research. Stereotype-based reasoning takes an initial impression of the user and uses this to build a detailed user model based on default assumptions (Kay 2000). Stereotypes were first introduced in GRUNDY (Rich 1979; 1983), a system for recommending books of interest to the user; the selection of books was done based on certain user characteristics. In order to construct a model of a person, at the beginning of each session, GRUNDY asked the user to provide a few self-descriptive words. These words were then used to infer the user’s personal traits and based on them, the system categorised the user in one or more of the predefined stereotypes. This approach, though appropriate for a recommender system, does not seem very suitable in cases of student modelling. Students are often incapable of providing an accurate measurement of their knowledge; they may overestimate or underestimate their capabilities depending on their self confidence.

Trying to overcome some of GRUNDY’s drawbacks, KNOME (Chin 1989) made use of a double-stereotype. KNOME was the user modelling component of UC (Wilensky, Chin, Luria, Martin, Mayfield and Wu 2000), an intelligent help system for UNIX users. It has one set of stereotypes for representing the user's expertise and another for representing the difficulty level of the domain information. KNOME monitors the user's first interactions with the system in order to infer her/his knowledge level. After adequate evidence has been collected, the system models the user in one of its predefined stereotypes. Similarly to KNOME, we use one stereotype to model the student’s knowledge level and one to represent the difficulty level of the concepts being taught. However, our approach differs from that of KNOME in that apart from the two stereotypes we also use stereotypes to model some important student attributes, such as her/his carefulness. Another difference is that in our system, the student’s level of knowledge is being updated after each session, unlike KNOME, which does not alter its conception of the user’s level of expertise after having determined the particular stereotype that the user belongs to. Finally, as Chin points out, KNOME does not address the problem of modelling users of operating systems other than UNIX, which is the domain of KNOME. In the case of Web-PVT, the system is able to model students that already know some language other than English, which is the domain of Web-PVT.

One interesting approach in managing a learner model in a CALL system is the one used in CASTLE (Murphy and McTear 1997). In CASTLE, knowledge is organised in a network of concepts, with nodes representing concepts and arcs representing relations between concepts (e.g. whether some concept must be taught before another). Each student is classified to a stereotype category, namely novice, beginner, intermediate and advanced. The default assumptions of this category are used to draw conclusions about what the user knows. In addition, a long term student model is constructed about each student and is updated each time new information about the student is acquired. Our approach is similar to that of CASTLE, but we model the student along several dimensions rather than one. These dimensions include the knowledge level of the student, an estimation of her/his carefulness while solving exercises and prior knowledge of other languages. In CASTLE the only dimension considered is that of the student’s knowledge level and they do not deal with the problem of language transfer.
Furthermore, we use the student modelling component for a wider range of tasks within the CALL system than CASTLE. One such important task is adaptive navigation support.

3. Representation of the Domain and the Student Model

The key to adaptivity in Web-PVT is the system's knowledge of the domain being taught. To enable communication between system and learner at content level, the domain model of the system has to be adequate with respect to inferences and relations of domain entities with the mental domain of a human expert (Peylo, Teiken, Rollinger and Gust 2000). In this sense, the domain knowledge of Web-PVT is represented in a conceptual network that depicts the interrelations between the several grammatical concepts of the domain of the passive voice of the English language. Representing the domain knowledge in a structured way ensures that the system “knows” the dependencies between concepts, and uses this knowledge to individualise instruction and provide adaptive problem solving support and feedback to errors.

Similarly with KNOME (Chin 1989) the grammatical concepts are grouped in categories based on their level of difficulty. These stereotype categories include simple, mundane and complex concepts. In Web-PVT the identification of the stereotype hierarchy was a result of an empirical study conducted before the system’s development. Each node in the domain knowledge represents a category of concepts, which may be further divided into smaller sub-concepts. There are three kinds of link between nodes: part-of, is-a, and prerequisite. A part-of relation points from a more general to a more specific concept, which is one of its parts. For example, the “verb tense conversion” concept, is a part of the mundane concepts. An is-a relation, points from an instance of a concept to the concept. For example, there is an is-a relation between the verb tense forms and the “verb tense” concept. A prerequisite relation points from a concept to another, which is its prerequisite. For example, in order to master the simple past, one should know how to form irregular verbs.

The domain concepts are associated with hypertext pages of the structured theory hyperdocument of Web-PVT. For each concept in the domain knowledge, a number of concepts may be prerequisite, while some factors (e.g. the knowledge level of the student) may render the studying of this concept redundant. Based on the student’s actions while interacting with the language tutor, the system distinguishes between three possible states of concept, namely “not read”, “read and not known”, and “read and known”. A concept is considered “not read” if the student has not studied the part of the theory that is associated with the concept. “Read and not known” are the concepts for which the student has visited the hypermedia page discussing this concept, but s/he did not manage to solve correctly exercises that evaluate this concept to a satisfactory percentage. Finally, a concept is considered “read and known” by the student if s/he has studied the theory part that is associated with this concept and s/he has also solved correctly exercises evaluating the concept to a satisfactory percentage. If a student has solved correctly exercises related to a concept in a percentage greater than a predefined “threshold”, without the student having read the relevant part of the theory, then the concept involved and all its prerequisite concepts are marked as “read and known” in the student model. For each theory page visited during a student's interaction with Web-PVT, the corresponding concept is marked as “read and not known” in the model of this student.

However, when the student starts working with the ICALL system, there is no information about what concept s/he has studied and whether s/he is able to solve correctly exercises related to that concept. In this case, the default assumptions of the stereotype that the student is assigned to are used in order to set initial values to the student model concerning the state of each concept. The process of initialisation of the student model is described in more detail in a subsequent section.

In addition to the students’ knowledge about grammatical concepts, the student model also comprises information about common student errors. Common student mistakes have been classified into nine broad categories of error that may be recognised by the system. These errors are associated with the conversion of passive into active voice and vice versa and also the prerequisite grammatical concepts, such as irregular verbs. The categories of error are:

1. **Accidental slips**: These are occasional actions, which are not systematic and which the learner herself/himself can correct. For example, the student may have deleted some words and may have forgotten to complete the sentence.

2. **Spelling mistakes**: for example, “mather” instead of "mother".

3. **Article mistakes**: for example, “a apple”.

4. Irregular verb mistakes: for example, the student may have used the usual ending “ed” to create the past participle of an irregular verb.

5. Absence or redundant presence of the agent: for example, “she is said by people to be beautiful” instead of “she is said to be beautiful”.

6. Mistakes in the word that connects with the agent: for example, “Irish coffee is made by whisky” instead of “Irish coffee is made with whisky”.

7. Verb tense conversion mistakes: for example, “Dinner is serving” instead of “Dinner is being served”.

8. Singular/Plural mistakes: for example, “The police has arrested him” instead of “The police have arrested him”.

9. Errors in the special cases of the passive voice: for example, “I was let to go out” instead of “I was allowed to go out”.

Each category of error may also be associated with a variety of explanations about the possible cause of the mistake (Virvou, Maras and Tsiriga 2000). Explanations have been based on identified strategies that learners may use in order to simplify the task of learning a second language (Richards 1974):

I. Language Transfer: The learner uses her/his mother tongue (or possibly some other foreign language distinct from the target language) experience as a means of organising the second language. Almost every category of error could be explained by means of language transfer. For example, a Greek student may have typed “English are spoken all over the world” instead of “English is spoken all over the world”, since the translation of the noun “English” is plural in Greek.

II. Overgeneralisation of the target language rules: The learner has acquired a particular piece of linguistic knowledge and some strategies, which s/he has found helpful in organising the facts about the target language, but applies them too widely. This explanation is also associated with many of the categories of error. For example, if the student forms the past participle of an irregular verb using the suffix “-ed”, this may be explained due to her/his overgeneralisation of the rule that the past and past participle of irregular verbs is formed with the suffix “-ed”.

III. Ignorance of rule restrictions: Mistakes of almost any category may be attributed to this explanation. For example, a student may type: "this table is made by wood" instead of "this table is made of wood" (word that connects with the agent mistake).

IV. Incomplete application of rules: Incomplete application of rules involves a failure to learn more complex types of structure because the learner finds s/he can achieve effective communication by using relatively simple rules. For example, in mistakes concerning the absence of an agent the student may have typed: "the flowers were bought" instead of "the flowers were bought by Helen".

V. False concepts hypothesised: False concepts may be derived from faulty comprehension of a distinction in the target language. For example, verb tense conversion mistakes may be attributed to this cause if the student has not understood correctly how to convert a verb in the passive voice.

VI. Carelessness: Errors that are due to carelessness of the student.

4. Initialisation of the Student Model using Stereotypes

When a student starts working with an ITS, the system has no prior knowledge about her/his proficiency level of the domain nor of her/his learning characteristics. The problem of initialising the user model is often solved using stereotypes (e.g. Ballim and Wilks 1991, Huang, McCalla, Greer and Neufeld 1991, Murphy and McTear 1997, Rich 1979). According to Kay (2000) a stereotype consists of:

1. A set of trigger conditions, which are boolean expressions that activate a stereotype,
2. a set of retraction conditions that are responsible for deactivating an active stereotype, and
3. a set of stereotype inferences that serve as default assumptions once a user is assigned to a stereotype category.

Some triggers may also act as essential triggers, which means that like any trigger they activate a stereotype, while the negation of them serves as a retraction condition.
4.1 Student Stereotypes along Three Dimensions

In Web-PVT, the student is classified to stereotypes along three dimensions. One dimension concerns the knowledge level of the student. There are four distinct stereotypes for this dimension, namely novice, beginner, intermediate and advanced. A second dimension concerns the degree of carelessness of a student. In this case, there are three stereotypes, namely very careful, averagely careful and careless. Finally, a third dimension concerns the student’s knowledge of other languages. In particular, there are stereotypes associated with the student’s mother tongue and stereotypes associated with other foreign languages that the student may already know. At the moment, the stereotypes about the mother tongue are restricted to Greek students or non-Greek; similarly, the stereotypes about other foreign languages that the student may already know are restricted to French and German, which are the most common languages taught as foreign languages at Greek schools.

Students are initially assigned to one of the stereotypes associated with each stereotype dimension, depending on their performance on a preliminary test as well as their answers to a questionnaire. In particular, the student is initially assigned to one of the four stereotypes associated with knowledge level, according to her/his performance on the preliminary test. The test has been constructed by human experts so as to contain representative questions that cover the whole domain of the passive voice of the English language. The test is given to the students before they have ever interacted with Web-PVT. Then the system asks students to self-categorise themselves in one of the three stereotypes associated with students’ carefulness while solving exercises. Finally, students are classified to stereotypes concerning their mother tongue and knowledge of other languages depending on the answers that they give to explicit questions, such as: “What is your mother tongue?”. The default assumptions of each particular stereotype that becomes active for the student are then used to make inferences about all aspects of the student model.

The trigger conditions that are sought in the preliminary test depend on the students’ errors. For example in the case of a beginner student, a trigger condition is the fact that s/he commits errors in the verb tense conversion to the passive voice in a percentage that is greater than 60%. That is because the concept of the verb transformation is considered mundane according to the domain knowledge hierarchy. As the system acquires more information about a particular student, it may use it to alter the active stereotype for that student. To do this, the system uses the retraction conditions of the stereotypes. In the case of the beginner stereotype, a retraction condition may be that the student makes mistakes in irregular verbs in a percentage less than 30%. In this case, the beginner stereotype would be deactivated and the novice stereotype would be activated instead. This is so because the irregular verbs are considered a precondition concept to the domain of the passive voice.

4.2 Stereotype Inferences

In Web-PVT, stereotype inferences are default assumptions concerning the state of each concept of the domain (“not read”, “read and not known”, “read and known”) with respect to the knowledge level of the student. For each concept in the domain knowledge, there is a concept-value pair associated with it in the student model. In order to set initial values for each concept in the student model the initialisation procedure takes into account the stereotype category that the student belongs to and the category of the concept concerning its difficulty (simple, mundane, complex). The default assumption of each knowledge level stereotype category concerning the state of each category of concept is presented in Table 1.

<table>
<thead>
<tr>
<th>Stereotype</th>
<th>Simple</th>
<th>Mundane</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>“not read”</td>
<td>“not read”</td>
<td>“not read”</td>
</tr>
<tr>
<td>Beginner</td>
<td>“read and not known”</td>
<td>“not read”</td>
<td>“not read”</td>
</tr>
<tr>
<td>Intermediate</td>
<td>“read and known”</td>
<td>“read and not known”</td>
<td>“not read”</td>
</tr>
<tr>
<td>Advanced</td>
<td>“read and known”</td>
<td>“read and known”</td>
<td>“read and not known”</td>
</tr>
</tbody>
</table>
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In the case of student errors, there is often the problem that a specific error may be associated with a variety of explanations. In such cases, the system has to select an explanation, which seems most appropriate for the specific student. To resolve such ambiguities, Web-PVT uses default assumptions that involve associations of explanations with error categories, depending on stereotypes. For example, students with high proficiency in the domain usually commit spelling and irregular verb mistakes due to their carelessness, while beginners commit the same mistakes due to other more serious causes, such as ignorance of rule restrictions (Table 2, Table 3). However, there are times when one dimension of the student stereotype is not sufficient to resolve an ambiguity. For example, in the “advanced” stereotype, a spelling mistake, such as “informations” instead of “information”, may be due to carelessness or language transfer. If the particular student also belongs to the stereotype “averagely careful” and “already knows French”, then the ambiguity is resolved and the error is attributed to language transfer rather than carelessness.

Table 2. Inferences of the “Advanced” Stereotype about Explanations of Errors.

<table>
<thead>
<tr>
<th></th>
<th>Spelling</th>
<th>Irregular Verb</th>
<th>Agent connecting word</th>
<th>Verb tense conversion</th>
<th>Singular/Plural</th>
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<td></td>
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<tr>
<td>Ignorance of Rule Restrictions</td>
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<tr>
<td>False concepts hypothesised</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carelessness</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Inferences of the “Beginner” Stereotype about Explanations of Errors.

<table>
<thead>
<tr>
<th></th>
<th>Spelling</th>
<th>Irregular Verb</th>
<th>Agent connecting word</th>
<th>Verb tense conversion</th>
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5. Individualising the Student Model

Stereotypes are very powerful at providing information based on few observations. However, they do not permit the formation of an accurate individual student model. Therefore, apart from using the default assumptions of the stereotypes that the student belongs to, Web-PVT also constructs a long term student model. The information of this model is used for the activation and deactivation of the various stereotypes as well as to individualise instruction and feedback.

The long term student model constitutes a history model of the student’s weaknesses and progress. It is constructed based on direct observations of the student’s use of the system, as well as on inferences from the active stereotypes for a specific student. This model keeps information about which concepts of the domain are already mastered and to what extent. In particular, the student model is updated accordingly each time a student visits a theory page or solves an exercise. In case the system has no evidence about the student’s mastery of a domain concept, it uses the default assumptions derived from the stereotype (novice, beginner, intermediate or advanced) that is active for the student. On the other hand, there is the case when the system has adequate information to provide an estimation of the student’s mastery of a concept based on the observation of her/his own answers and studying activity.

The long term student model is also responsible for providing information concerning the stereotype of the student that concerns her/his carefulness while solving exercises. For example, if a student has self-categorized herself/himself as careful while solving exercises, but s/he has been
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recorded by the system to make trivial typographic errors in a percentage greater than 75%, then the careful stereotype should be deactivated and the careless stereotype should be activated instead.

Furthermore, the long term student model keeps a record of the proneness of the student to commit each category of error along with the most common explanation for that category. In some cases a mistake of the student may be attributed to more than one categories of error and/or explanations. In such a case, an ambiguity arises and the system should consult the student’s long term model and stereotype in order to resolve it. For example, if a user is given the sentence: "Jim drives expensive cars" and is asked to convert it to passive voice, the correct answer would be "Expensive cars are driven by Jim". However, if the student types the sentence "Expensive cars are drive by Jim" where the verb "drive" is not in the past participle, then this mistake may be attributed to two categories of error. It could either be an accidental slip, caused by the student's carelessness or a verb tense conversion mistake, caused by the hypothesis of faulty concepts. If the particular student has not previously made any conversion mistakes and generally does not seem to hypothesise faulty versions of a concept, but has frequently made accidental slips then this would have been recorded in her/his long term student model. In this case the system would favour the accidental slip as the most probable cause of the ambiguous mistake.

6. Adaptive Tutoring Based on the Student Model

The student model is mainly used to provide adaptivity to the system. Adaptivity is a highly desired feature of Web-based educational software, since distance learning systems are aimed to be used by many different students and in situations where no teacher is available to help users in their learning process. Web-PVT incorporates techniques from Intelligent Tutoring Systems and Adaptive Hypermedia to tailor instruction and feedback to each individual student (Virvou and Tsiriga 2001). In particular, based on the information contained in the student model the system supports the student while s/he navigates through the course material. Moreover, in order to further individualise instruction, Web-PVT consults the student model before presenting the student with new exercises to solve. Finally, the student model is also utilised in order to perform error diagnosis and advice generation in cases of error when solving to exercises. In the following sections we describe the approach taken in Web-PVT, to address the above issues.

6.1 Adaptive Navigation Support

Due to extra navigational freedom they provide, hyperdocuments impose greater cognitive loads on users than linear documents, such as books on paper or on-line (Calvi and De Bra 1997). Therefore, although a good design of the navigation space may help, it is also necessary to provide more sophisticated mechanisms that modify the navigation alternatives by some sort of adaptation procedure (Caro, Pulido and Rodriguez 1999). One way to support users while they navigate through a hypermedia space is by adapting the links of this space based on the model of each individual user. Link adaptation tries to simplify the rich link structure to reduce orientation problems, while maintaining a lot of navigational freedom, a typical property of hypermedia systems (De Bra, Houben and Wu 1999).

Brusilovsky (1996), distinguishes between five techniques that can be used to provide link adaptation: direct guidance (Stern and Woolf 1998), link sorting (Hohl, Böcker and Gunzenhäuser 1996), link hiding (Brusilovsky and Pesin 1998), link annotation (Weber and Specht 1997) and map adaptation (Micarelli and Sciarrone 1996, Furnas 1997). With the direct guidance technique, a "next" or "continue" button is shown to the student. This button leads the student to the particular page that the system considers most appropriate for the student to visit. The direct guidance technique is clear and does not lead to cognitive overloads. However, it restricts the student to either follow the system's suggestion or receive no support. According to the link sorting technique, the available links in the hypermedia space are ordered on the basis of the student model, displaying the most relevant links first. However, adaptive link sorting makes the order of links not stable, often leading to problems with incorrect mental maps (Brusilovsky and Eklund 1998). Using the adaptive link hiding technique, the links that are not ready for the student to visit are hidden from the student. The hiding of links can be achieved either by totally removing the link or by transferring links to normal text. Link hiding is more transparent than link sorting. However, earlier research has shown that in general, users feel
uncomfortable about links being removed, because they know there is more material they can ultimately visit but they do not know how to reach it (Calvi and De Bra 1997). The idea of adaptive annotation is to augment links with some form of comments, which can tell the user more about the current state of the nodes behind the annotated links. These annotations can be provided in textual form or in the form of visual cues. A problem with this technique is that due to the fact that it adds a feature to the interface, it could lead to a cognitive overload, which may distract users from the content (Brusilovsky and Eklund 1998). Finally, the idea of map adaptation is to individualise the form of the graphical presentation of the link structure of the hypermedia space. However, personalised views, such as site maps are particularly useful in cases where the hypermedia space is considerably large.

In order to overcome some of the problems of the distinct adaptive navigation techniques, Web-PVT uses a combination of two link adaptation techniques to help the student while navigating the structured theory hyperdocument; namely adaptive link annotation and direct guidance. In this way, the student has the ability to choose among the more restrictive direct guidance technique to visit the page that is best suited to her/his current knowledge level, or to decide which page s/he wishes to read based on the help provided by the annotation of the links. In particular, Web-PVT uses different font types and icons to annotate the links of the table of contents and other pages, when the student navigates through the theory hyperdocument. The system distinguishes between four different states of link: highly recommended, ready and recommended, visited and known and not ready. Highly recommended links are associated with concepts that are marked as “read but not known” in the student model. Ready and recommended are the links that point to pages that discuss concepts that are marked as “not read” in the student model, but all its prerequisite concepts are marked as “read and known” by the student. Links that are considered visited and known point to concepts that are considered “read and known” by the student. Finally, links that are not ready to visit point to concepts for which there is one or more prerequisite concepts that are marked as “not read” or “read and not known” in the student model.

Apart from adapting the presentation of links, in each of the theory pages visited by the student, a “Next” button is always visible pointing to the theory page that the system considers the most appropriate theory part for the student to study. The selection of the next most appropriate page to be presented to the student is based on the long term student model. In case there is one or more concepts that are marked as “read and not known” in the model of the student, the tutor selects a page presenting one among them. If there is no concept that is “read and not known”, the system selects one among the concepts that are marked as “not read” in the student model, and for which all the prerequisite concepts are “read and known” by the student. Finally, if the student has completed the studying of all the concepts, the system informs her/him about it and prompts the student to evaluate her/his skills by solving exercises.

An example of the adaptive annotation of links and "Next" button in the table of contents is illustrated in Figure 1.
6.2 Individualised Exercise Selection

The tutor has limited capability of judging whether a concept is known to a student and to what extent, unless the student's mastery of a concept is evaluated through exercise solving. Therefore, a solving exercise mode is very crucial in adaptive educational systems. Web-PVT supports four types of exercise for the student to solve. The first type consists of multiple choice exercises, where the student has to choose the correct answer from a set of possible answers in order to complete a sentence in the passive voice. In the second type of exercise, the student has to enter free text in order to fill in the blanks of a sentence in the passive voice. The final two types of exercise present a sentence in one voice (e.g. active voice) to the student and ask her/him to rewrite the sentence to the other voice (e.g. passive voice).

In order to select the next exercise to present to the student, Web-PVT consults the long term student model. In case there is one or more concepts marked as “read and not known” in the student model, the tutor selects an exercise evaluating as many of those concepts as possible. For example if the student has visited the theory pages associated with the concepts “irregular verbs” and “agent connecting word” but has not been able to solve exercises evaluating those concepts to a satisfactory percentage, the tutor would present her/him a “fill in the blanks” exercise of the form “This table is … wood” (correct answer “made of”).

If there is no such concept that is considered “read and not known” for the student, the system selects a concept for which the student has the lowest percentage of correctly answered exercises and presents an exercise testing this concept. In this way the system is able to provide the student with exercises that are neither too difficult nor too easy for her/him to solve.

6.3 Individualised Advice on Students’ Errors

Error diagnosis and advice generation is performed by Web-PVT when the student is solving exercises. In multiple choice exercises error diagnosis is simple. For every erroneous answer that the student may select, there is an associated misconception. The system consults the student model in order to determine how careful a student is while solving exercises, before presenting to the student the error message that is associated with the selection s/he has made. In case the student belongs to the “careless” stereotype, the system consults the long term model of this particular student, to find out whether the student seems to know the concepts that this question evaluates. If the student seems to have mastered these concepts, Web-PVT infers that the student's mistake was due to her/his carelessness and not due to some more serious reason. Else, the system presents to the student the error message that corresponds to the erroneous selection of the student.

In cases where the student is asked to enter free text as an answer to an exercise (fill in the blanks and rewrite a sentence exercises), error diagnosis becomes more sophisticated since in these cases the student is allowed to be more creative than in multiple choice exercises. ICALL systems have commonly based their error analysis (at least partly) on the mother tongue of the student. However, Web-based systems are addressed to a more international audience and hence there is a need to expand their framework. Therefore, Web-PVT also comprises knowledge about errors that are independent of the mother tongue of a student and other languages that s/he may be learning. Mal-rules related to language transfer are used in case the mother tongue of a student is known, while general mal-rules are used in cases when there is no information about the native language of the student. Furthermore, the student's level of knowledge is used in order to determine the amount of help provided to the student while s/he is solving exercises. The less proficient a student is the more help s/he receives.

7. Conclusions and Future Work

Web-PVT uses a flexible student modelling component to provide adaptive instruction. In particular the system uses stereotypes along several dimensions in order to initialise the student model. In addition, it forms an individual student model for each user and performs error diagnosis. The emphasis on the student modelling component of the Passive Voice Tutor has been put on the bi-directional interaction of two sub-components: the set of stereotypes that the student belongs to and the individual long term student model.
The student model of Web-PVT is utilised in three different ways. First, it is used to support the student while s/he navigates through the course material. Second, the exercises that are presented to the student are selected based on the current knowledge and misconceptions of the student. Finally, the student model is also utilised in case of error diagnosis and advice generation. In order to perform error diagnosis, the system tries to give explanations about students’ mistakes. In cases of ambiguity, Web-PVT consults the individual student model and/or the stereotypes that are active for the specific student and disambiguates between the competing explanation hypotheses. Furthermore, Web-PVT is provided with a list of the most common errors and their corresponding explanations, according to the stereotypes where the student belongs to. The multi-dimensional stereotypes are determined depending on the student’s knowledge level at the English language, degree of carefulness, knowledge of other languages and interference from mother tongue.

Within the future plans of this research, is the improvement of the student modelling component, so that it may cope with temporal aspects of the student learning process in a more sophisticated way. These temporal extensions will include acquisition and retention factors, which will model how quickly a student masters a concept and how well s/he recalls a known concept over time, respectively. In addition, the student modelling component will be extended in order to model the student in terms of her/his learning preferences, for example whether s/he prefers studying a concept by reading the corresponding part of the theory or by studying examples.

References


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