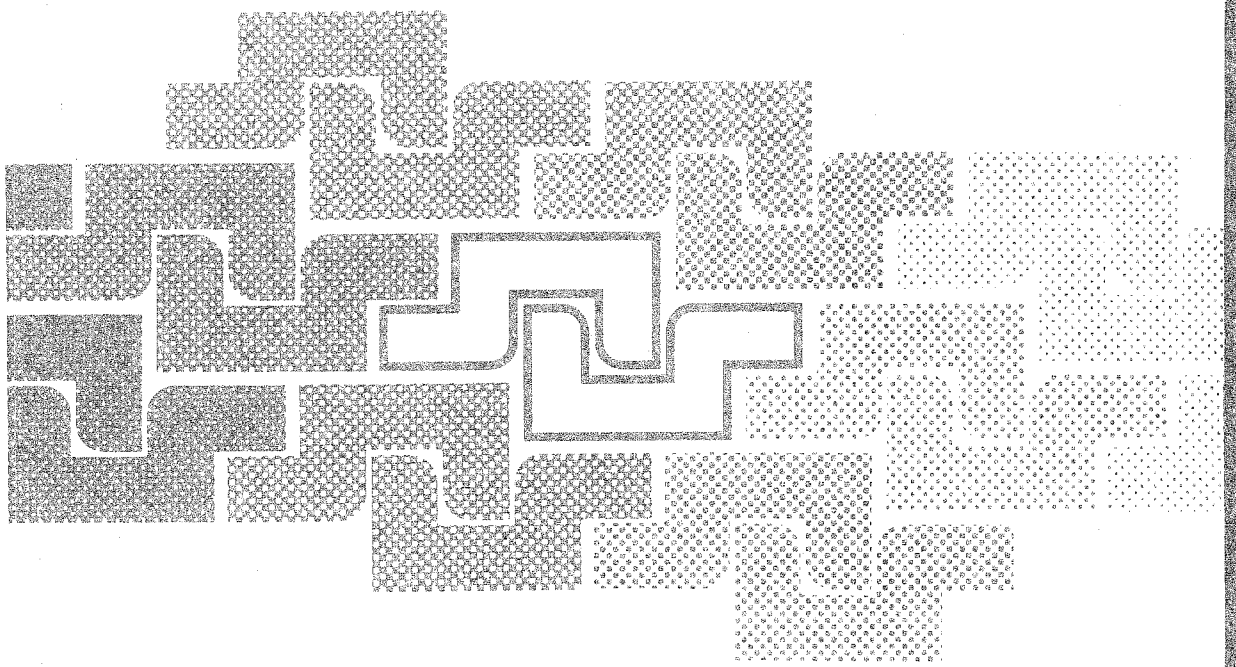

Intelligent Tutoring Systems for Foreign Language Learning

The Bridge to International Communication

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Introduction

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Advances in artificial intelligence (AI) in education applications have improved the potential of developing intelligent instructional systems that can actually be used in the classroom. Progress in natural language processing (NLP) has also improved the way in which computers handle natural language input. It seems propitious, therefore, that we look at these two technological advances in the application of foreign language (FL[1]) intelligent tutoring systems (ITS). Despite these advances, the challenge of integrating ITS and NLP into one hybrid system is a formidable task. The papers in this book, and others presented at the Workshop, address that challenge and present current research in the field representing laboratories from 10 different countries (Australia, Canada, England, France, Germany, Greece, Italy, Scotland, Turkey, U.S.A.).

Intelligent Tutoring Systems for Foreign Languages

Language instruction delivered on computers is not new, but the enhancement of such instruction with AI technology in computer systems is. Computer-assisted language learning (CALL) has been used in foreign language instruction for some time with varying degrees of success [11]. This CALL approach to computer-delivered instruction generally uses predefined branching routines and static error feedback messages to guide learners. More adaptive, individualized instruction is feasible with AI techniques that model learner performance and deliver goal-based and remedial instruction to move the learner through the material [5, 13, 8]. This kind of computer-based instruction is the basis for ITS. The domains that have been most used in recent ITS development are for the most part tractable and formally defined (mathematics, physics, electronics). Of course, not all of the problems in ITS research have been solved in these domains. Nevertheless, some very promising ITS exist that are used in training settings (e. g., the Geometry ITS [2]).

In less well-defined domains such as language learning, many important issues are emerging that were not encountered in the traditional ITS domains. Some of these issues involve (1) the representation of linguistic knowledge in the expert and learner[2] models, (2)

[1] I would like to comment on the use of both foreign and second language learning (FLL and SLL in this book). Both terms refer to the acquisition of a non-native language. In some communities, the language is a second language (e.g., Canada with English and French); in large monolingual societies the second language is often referred to as a foreign language. We argued about appropriate terminology at the Workshop, but no obvious resolution was found. One can argue that for some learners, it is third or fourth language learning- but 'Fourth Language Learning' seems strange to consider! On the other hand, all non-native languages can be viewed as foreign until learned adequately; this seems to be the best general term to use. This definition is not accepted universally in the field. The reader will therefore see both references (FLL and SLL) used in the book which reflect either the sociocultural definition for non-native language learning in a country or personal preference.

[2] In ITS, the term 'student' model is generally used when referring to the person acquiring some skill. We discussed the terms 'student' and 'learner' and their relation to language skill acquisition during our working sessions. Borrowing from Self [12] we use term 'learner' in the editors' introductory comments since it reflects more active participation and collaboration in the learning process on the part of the learner.

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implementing parsers that must process ungrammatical input and reason about it in view of learners' predictable interlingual productions during learning, (3) representing tutoring knowledge that is appropriate for language learning (teaching strategies and principles for language learning are different from other types of skill learning), and very importantly, (4) understanding the foreign language acquisition process.

Many of these issues will involve a considerable research effort before effective FL ITS becomes a reality in the classroom; and we do not wish to claim that all these problems have to be solved before such a system is developed. Indeed, we shall no doubt be wrestling with some of these issues for some time. Nevertheless, we examined selected issues from those listed above at our Workshop and discussed their role in the development of an ITS architecture for foreign language learning. This book, as a compilation of some of the papers presented at the Workshop, presents an overview of the current state of the art and recent contributions made to the field.

In order to understand the issues that face FL ITS research, the reader should be familiar with the basic architecture for an intelligent tutoring system. An ITS is made up of four basic modules: the expert model, the learner model, the tutor model, and the interface or environment for communicating with the learner. The reader is referred to many excellent books that give more detailed information about ITS in other domains and ITS architectures [8, 12, 14, 16, 17, 19]. These modules are briefly reviewed below with a description of the unique requirements for developing FL ITS.

The Expert Module for a Language ITS

The expert module of an ITS provides the domain intelligence for the system [1], a model of the expert. For any given domain, not only must we decide what knowledge to include in the expert model, but also, how we should represent or encode it. Anderson [1] provides an overview of the three primary approaches to codifying expert knowledge: black box models, expert systems, and cognitive models; and discusses the trade offs for each approach in terms of implementation effort and pedagogical effectiveness. In language domains, we will find that certain approaches are more appropriate than others, given the nature of linguistic knowledge, even though the implementation costs are high.

This ITS module represents the domain-specific expert knowledge and the inferencing or reasoning processes involved in solving problems in the instructional domain. In language domains, this means we need some type of grammar and a lexicon for the target language (the expert knowledge), and a parser (the expert inference engine) to process language inputs.

The grammar is used to define the legal rules for that portion of the language to be taught. This component of the expert knowledge base usually follows some syntactic theory (e. g., Definite Clause Grammar, Functional Unification Grammar, Lexical Functional Grammar, General Phrase Structure Grammar, and Tree Adjoining Grammar (TAG) [3]) used to formally represent a particular grammar. However, a linguist's formal grammar is not the intention in the construction of this portion of the expert knowledge. Foreign language teachers don't teach formal grammars, but rather some subset of the grammatical system for a language that is to be acquired by the learner for productive, communicative purposes. Similarly, the coverage in the language ITS must be mindful of this requirement. The expert model's grammar knowledge need not be exhaustive

However, the reader will find both 'student' and 'learner' used in the papers presented herein. These terms can be thought of as synonyms (Ask George what relations WordNet would have for these nouns.)

[3] Readers are referred to [9] more more information on these formalisms. Tag is described in Chapter 5 in this book.

therefore, but adequate for the skill level (beginning, intermediate, advanced) to be addressed by the system.

A lexicon is another component in the knowledge base to provide coverage for the words to be acquired by the learner, and that will permit the parser to understand language input during various activities and learning experiences. Some type of formalism is required to represent the semantics for the lexicon so that meaningful parsing can be accomplished for words used in context. Language learning is not simple vocabulary learning where an item in L1 is mapped directly to its correspondent in L2[4] . The context surrounding a word has much to do with specifying what word or idiom is used to appropriately communicate some meaning. But representing semantics and limited pragmatics in an ITS is a very hard research problem. Nevertheless, the system should ideally have some form of world knowledge and context to illustrate how language is used in natural settings.

The parser provides the means for the computer system to reason about and process the language, and it is the last major component in the expert module. In FL ITS, the challenge is not only to provide natural language understanding capabilities, but to allow for processing imperfect input since learners never have complete control of the L2 used. Parsing natural language in a FL ITS involves not only a means of interaction for the learner with the system, but also understanding the domain skill itself that is being taught. This is a unique characteristic for NLP in language ITS implementations. The parser must be capable of accepting divergent input strings from learners and be able to identify a plausible divergence from nonsensical language so as to be capable of reasoning properly about learners' attempts to use the L2.

The Learner Module for a Language ITS

The learner module in an ITS includes the information that describes a learner's knowledge about what is being learned and allows the tutor module to adapt instruction [18] and provide appropriate feedback. Self [11] refers to this model as a set of programs designed to represent a learner's knowledge state. VanLehn [18] specifies two components that make up the learner model: the structure or representation of the knowledge in the model and the process that manipulates that knowledge structure. This process is termed 'diagnosis' and the outcome is termed 'knowledge state assessment'.

In order to properly model the learner and perform diagnosis, the system must have knowledge about learner errors. In traditional ITS, these errors are stored in bug catalogs or lists of mal-rules that get accessed when the system is engaging in learner diagnosis. While similar methods can be employed in FL ITS, the nature of the error and the way the system should understand it are different for foreign language learning (See Chapter 8).

In a foreign language domain, the representation of the knowledge in the learner model must use the same computational formalisms as in the expert model. This is so that during the process of diagnosis, the system can compare the two knowledge states using some acceptable modeling technique. Thus we can expect some type of formal grammar and lexicon in the learner model similar in form to those used in the expert module. The process of diagnosis has traditionally used techniques such as overlay or differential models [14] or model tracing [1, 18]. In language learning where communicative skills are stressed and situation dependent, other modeling techniques may be needed. Several papers in this book describe implementations of these and other techniques more suited to language learning.

Building and maintaining such a learner model is generally considered a difficult and costly task. Constructing a 'deep' model may not be a priority in certain cases (e. g., learning language for communicative purposes where the idea expressed counts more than

[4] L2 refers to a foreign or second language; L1 refers to one's native language.

the actual grammatical construction used), but in other circumstances, a deeper learner model is unavoidable (e. g., when diagnosing grammar errors is important). A set of design principles for bypassing some of the problems encountered in constructing a deep model [12] should help FL ITS researchers with this problem.

The Tutor Module for a Language ITS

This module represents the tutoring strategies and instructional goals used to deliver instruction in the system. The tutor module in an ITS is responsible for enabling the student to solve problems in the domain. Teaching students how to acquire a skill is difficult because the computer tutor must be able to adapt the instruction to individual needs. This means that the tutoring system needs to know about the learners' performance, be able to advise them during a learning segment, suggest or present new activities based on inferences made about current performance, and be able to provide meaningful feedback when errors are made. These capabilities indicate how important the communication between the tutor and learner modules is. Tutoring approaches in ITS can vary depending on the skill to be learned and the instructional purpose of the ITS (e. g., discovery learning, grammar drills, review exercises). Traditionally, ITS has used tutorial dialogues, simulations, and plan-based instruction to represent tutoring knowledge in the tutor module. Learning environments are another alternative.

Tutorial dialogues as a means to convey instruction arose from the Socratic method of tutoring [14] and can be used to guide performance and provide hints or coaching to help the learner solve problems. Simulations in ITS are another tutorial technique. They are more easily implemented when the domain knowledge can be represented by formal rules such as electronic troubleshooting or steam plant mechanics [14]. In these domains, the instruction can be presented by having the computer simulate state changes in the device that learners must interact with as they solve problems. Plan-based instruction is another method that uses a set of instructional goals and curricular activities as part of the knowledge base in the tutor module. Plan rules embody pedagogical principles for a domain and are attached to the instructional goals for a particular lesson. Therefore, actual teaching strategies must be codified in the system. This is a particularly difficult approach since we understand so little about good human teaching strategies.

Learning environments, as an alternative to a formal tutor module, present instruction in an open, discovery-based system that students explore. No formal tutoring rules are used to move students from one knowledge state to another. Students are left to their own intellectual devices to experience and learn about what is made available to them. Good tutoring in these environments depends on the organization and presentation of the domain knowledge (See Section Four for some examples). If the student is to discover appropriate knowledge structures in the domain, then the representation of the knowledge must follow organizational principles that support the cognitive processes of the learner as s/he moves through the environment.

In a foreign language ITS, the type of approach selected for representing the tutoring knowledge should be based on an understanding of the unique nature of foreign language acquisition. Current theories of foreign language learning and teaching support the communicative approach [7, 9]. This means that the tutoring should use authentic, realistic language contexts for presenting new material to the learner. The papers we present in this book illustrate some promising methods, as well as challenges, for representing tutoring knowledge in a foreign language ITS.

The Graphical Interface Environment for a Language ITS

The learning environment is characterized by the graphical interface of the tutoring system. The features for this environment include the tools and noninstructional help that will guide the learner as problems get solved [3]. It is through the graphical interface in an ITS that all the instruction is communicated [19]; thus its design becomes very important for a language tutoring system. Burton [3] discusses several important issues for designing instructional interfaces, for example, the level of abstraction required by different domains, and the fidelity of graphical simulations for tutoring aspects of physical systems (steam plant fault diagnosis). In a foreign language ITS, the interface or learning environment should provide a means for entering language input to be parsed by the system as well as the use of different media (graphics, animation, text, sound, video) to present language in meaningful, communicative situations. This suggests the use of some type of mutiwindowing, multimedia design. Different media are especially important for language learning so that acoustic, semantic, and orthographic mappings to the L2 can be made. Current advances in graphical interface and multimedia technology provide us with new, exciting tools for creating the graphical interface. Many of the papers in this book illustrate the different multimedia approaches available for foreign language ITS interface implementations.

The Structure of the Book

The papers in the book represent a selection of those presented at the Workshop, and are organized into five different sections to reflect a conceptual focus for each group of papers. We used the Workshop topics to organize our presentations and focus our discussions (computational and theoretical foundations, learner modeling and error diagnosis, and tutoring strategies and learner control). We found that some of the papers addressed other areas not explicitly covered by these topics. The foreign language experts we invited to the Workshop were most concerned about identifying language learner characteristics and discussing practical issues related to using computers in the classroom. Since understanding these issues is a fundamental prerequisite to foreign language ITS research, we grouped these papers in Section One. The next three sections of the book present papers that explore some of the research problems we face in the development of the three principal ITS modules. These sections propose methods for solving some of the knowledge representation, computational, theoretical, and modeling problems we face. The papers presented in Section Two deal with the first topic. Here we grouped those papers that described theories of foreign language acquisition and processing, and computational formalisms for representing linguistic knowledge, as a theoretical basis for understanding foreign language ITS requirements. Section Three includes papers that describe modeling techniques for understanding what the learner knows about the L2 and methods for constructing learner models. These papers deal with the computational aspects of the second topic, but also depend on an understanding of learner characteristics and errors presented in Section One. Section Four presents papers that describe approaches to tutoring language in an ITS. These papers focus on using principled techniques and environments for presenting communicative foreign language tutoring with innovative use of multimedia. Section Five presents descriptions of working Intelligent CALL prototypes. These papers present current accomplishments and the technology promise in FL ITS research.

All of the Workshop participants are gratefully acknowledged for the lively discussion and critiques of the work presented during the Workshop, and their consideration of the research problems that remain to be solved. Their many fruitful ideas and contributions that arose in the working group sessions are reflected in the introductory comments for each section of the book.

The papers cover many different technical domains and therefore can be read in a modular fashion. We assume that our readers will come from foreign language teaching, computational linguistics, psychology and psycholinguistics, and computer science. You may may feel more familiar with certain sections or papers in the book depending on your background and interest. But we hope that you will read those other sections whose work is less familiar to you in order to understand the interaction between different fields in a multidisciplinary effort such as FL ITS development. We also hope that the reader will be able to gain from the work presented in this book and use it as a guide for continued research in the field.

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[5] These references are also referred to in the five introductory section comments in this book.

Section One

Teaching Practice: Understanding Technology and Language Learners

One of the first steps in the development of a foreign language ITS is to understand the characteristics of language learners and language teaching practice. In this section we present a group of papers that were prepared by foreign language teaching experts invited to our Workshop. In this introduction, we borrow from an essay presented at the Workshop by Alec Gogos, English professor, Aristotle University, on the practical perspective of computer-assisted language learning (CALL) in the classroom.

As a foreign language teaching expert, Dr. Gogos elaborated on two interesting views for CALL. One view embraces all the positive aspects of CALL, new technology, automated instruction, and instructional support for the teacher. Where previously the language teacher has relied on record and audiotape players, videos and filmstrips, and the language laboratory, we are now seeing the language laboratory concept encapsulated in one system: CALL. These systems provide multimedia presentations of language material with sound, animation, and online exercises. This is exciting, but we must not be seduced by mere technology; high tech toys will not in and of themselves perform miracles in the classroom.

The other view for CALL begins with an admission that foreign language learning is very different from learning other subjects. Everyone agrees that to become a graduate in nearly any subject (math, economics, or computer programming), one follows a four year program of study and then gets a diploma. This degree assures us that the graduate is knowledgeable in the subject, indeed a specialist or expert in the field. However, with language learning, the situation is somewhat different. After four years of study, the graduate may be considered a specialist in the field, but there is no guarantee that this individual will be comparable with a native speaker (an 'expert' in the field). This is especially true if the individual started the program with no prior knowledge in the language or if the program of study is in their native language environment.

Nevertheless, CALL has entered the classroom and there it shall stay. To use it effectively in the classroom, and to develop it into a more sophisticated intelligent tutoring system, we must first come to understand the language learner, the acquisition process itself, and how to best utilize this new technology for instructional purposes.

Chapter 1 expands on this practical perspective with a description of an evaluation of a CALL system presently in use at a German university. We are shown how CALL can be used to promote communicative interactions between learner and system. The authors also present a good description of learner characteristics from a psycholinguistic view of language acquisition. Their view of the learner as an 'experimenter' provides a good introduction to more detailed theoretical frameworks on foreign language acquisition presented in Section two of the book.

Chapter 2 in this section discusses language learners' errors and misconceptions that arise during learning. The authors have developed an analytic approach to extract diagnostic information about an individual's errors during a lesson. This approach uses an interactive dialogue where questions are used to probe learners' 'intuitions' regarding novel linguistic phenomena. Such empirical data plays an important role in error diagnosis in ITS research. We will revisit similar issues in error knowledge acquisition and the computational formalisms derived from this analysis in the section on Modeling the Language Learner presented later.

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