An intelligent computer- based tutoring approach for the management of negative transfer

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AN INTELLIGENT COMPUTER-BASED TUTORING APPROACH FOR THE MANAGEMENT OF NEGATIVE TRANSFER

Ph.D Thesis 1994

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Abstract

This research addresses how a prototype of a language tutoring system, the Chinese Tutor, tackles the practical problem of negative transfer (i.e. mother tongue influence) in the learning of Chinese grammar by English-speaking students. The design of the Chinese Tutor has been based on the results of empirical studies carried out as part of this research. The results of the data analysis show that negative transfer can be used to account for almost 80% of the errors observed in the linguistic output of students in their study of Chinese. If the students can be helped to overcome these errors, the standard of their Chinese will be greatly improved.

In this research, an approach of Intelligent Language Tutoring Systems (ILTSs) has been adopted for handling negative transfer. This is because there are several advantages of ILTSs, including interactive learning, highly individualised instruction and student-centred instruction [Wyatt 1984].

The Chinese Tutor contains five main components: the Expert Model, which contains all the linguistic knowledge for tutoring and serves as a standard for evaluating the student's performance; the Student Model, which collects information on the student's performance; the Diagnoser, which detects different types of error made by the student; the Tutor Model, which plans student learning, makes didactic decisions and chooses an appropriate tutorial strategy based on the student's performance; and the Interface Module, which communicates between the student and the system. A general and robust solution to the treatment of negative transfer, i.e. the technique of Mixed Grammar has been devised. The rules in this grammar can be applied to detect arbitrary transfer errors by using a general set of rules.

A number of students in the Department of East Asian Studies at the University of Durham have used the Chinese Tutor with positive results.

For My Parents

Acknowledgements

I am indebted to my supervisor Dr. Roberto Garigliano for his helpful advice and great support during the period of my research.

I am also grateful to Russell Collingham and Kevin Johnson for their constant support and encouragement; to Jonathan Hazan, Dr. Richard Morgan and Mark Smith for their help with programming; to Caroline Mason for providing an essential friendly home environment, and for useful feedback on my English and Chinese grammar; to Prof. John Harris and Prof. Keith Pratt from the Department of East Asian Studies, and the University of Durham for facilitating funding arrangements; to Dr. Jianrong Chen, Nigel Ellis, Amy Hong, Dr. Xiaohui Liu, Wing Yee Kwong, Nuan Sanguansak and Dr. Ying Shi for their friendship and support; and to other colleagues in my group (Chris Cooper, Stephen Jarvis, Deborah Lawrence, David Nettleton, Brett Parker, Sanjay Poria, Simon Shiu and Sengan Short) as well as staff and students of the Department of East Asian Studies for all their help.

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Extended Abstract

The purpose of the extended abstract is to illustrate some important points addressed in the *Abstract* and to give the reader a general idea of what the research is about. For further information about the thesis, please refer to the *Methodological Introduction.*

The objective of this research is to discover the common errors made by English-speaking students in their first-year study of Chinese grammar, and to design a technique for detecting these errors when they occur and help students overcome them using a computer-based language tool. The reason for designing such a tool is that, by helping students with these errors, it can save human teachers time, thus freeing them for more advanced work.

The results of our empirical studies indicate that almost 80% of the students' errors can be interpreted as errors of negative transfer, since negative transfer is the simplest explanation for these errors. Negative transfer is the use of a native language pattern or rule which leads to an error or inappropriate form in the target language. The term *negative transfer* is often used as a synonym for *mother tongue influence*, *the problem of transfer*, and *native language influence* in the field of second language acquisition. The above terms are used alternatively throughout the thesis.

In order to provide the reader with a clear understanding of this research, it has been divided into the following aspects: the scientific aspect, on why, through empirical studies, negative transfer seems to be a real problem in second language

learning; the technical aspect, on how the problem of transfer has been solved; the engineering aspect, on how the design of the system has followed good software engineering practice and finally, the practical aspect, on why the system is usable by the students.

Scientific Aspect

An effective tutoring system should be able to deal with *practical* problems in education [Clancey 1992]. Empirical studies can be used as an important means of discovering the real need for a working system. Sleeman suggested that it is hard to produce an effective tutoring system without having a good knowledge of the errors made by students [Sleeman 1982a]. The reasons behind our empirical studies are that there was little research data showing what difficulties encountered by English-speaking students when they learn Chinese, and linguists hold different views as to the common errors made by students in learning a second language [see *Section 2.1*].

The design of the Chinese Tutor has been based on the results of our empirical studies. The progress of first-year students in learning Chinese grammar has been monitored in the Department of East Asian Studies at the University of Durham, with data being collected between October 1991 and March 1992. The data collection [see *Section 2.2.2*] was based on the standard tests given by the Department to their students to check how well they mastered the grammatical points that they were taught in a particular week.

In the data analysis [see *Section 2.2.3*], the test papers were analysed with the types of error being classified. The numbers for each kind of error identified in the test papers for a particular week were added together and finally the number of each kind of error was worked out as a percentage of the total number of errors.

Little research has been done in second language learning to classify transfer errors. The transfer errors in this research have been classified according to the

generality of errors (i.e. how serious an error made by the student is). The reason for classifying the types of error is that the system will be able to deliver appropriate help to the student based on what type of error has been made. There are six kinds of error identified from the test papers: the syntactic transfer, the phrasal transfer, the lexical transfer, the syntactic error, the lexical error and the overgeneralisation error [see *Section 2.2.3*].

The results of the analysis [see *Section 2.2.4*] [Wang 1993] indicate that the errors of negative transfer (the syntactic transfer, the phrasal transfer and the lexical transfer) can be used to explain nearly 80% of the errors made by the students. The results show that negative transfer appears to be a significant factor in hindering students' learning of Chinese grammar. The empirical studies have highlighted mother tongue influence as a practical problem in students' learning of Chinese, a solution to the problem is needed in order to help students improve their standard of Chinese.

Technical Aspect

The approach that this research has taken towards managing transfer is to build an intelligent computer-based tutoring system [see *Section 4.1*]. We believe that through this approach, students can be assisted to eliminate mother tongue influence more effectively than by doing written exercises on their own. The main advantages of using such an approach include the ability to provide immediate feedback to the student, the individualised tutoring which can be tailored to the needs of the individual student, and the learning pace, which can be controlled by the student.

The Chinese Tutor contains five main models [see *Section 4.4*]: the Expert Model, the Student Model, the Diagnoser, the Tutor Model and the Interface Module. A technique of Mixed Grammar [Wang 1992] has been specially designed for handling arbitrary transfer errors. The five models of the Chinese Tutor operate

together effectively to help eliminate errors of transfer made by students in their study of Chinese [Wang 1994a] and [Wang 1994b].

The Mixed Grammar of Chinese and English is used for identifying errors of transfer automatically. This interwoven grammar consists of Chinese grammatical rules and the fragments of English rules, which have been selected according to empirical data.

The Expert Model embraces the domain knowledge which represents the subject of the tutorials and functions as a standard for evaluating the student's performance. The Student Model collects information about the student's current state of learning, keeps a record of his/her learning history and updates itself after each of the student's answers has been analysed. The Diagnoser correctly detects types of transfer error and non-transfer error, and evaluates to what extent the student has fulfilled the task. The Tutor Model plans the student's learning. It selects an appropriate tutorial strategy and makes didactic decisions based on the updated Student Model and the results from the Diagnoser. The Interface Module handles the final output of the system and interacts between the system and the student.

Engineering Aspect

The Chinese Tutor has been written in a lazy functional language (Miranda [see *Glossary*]); this has led to the code being easy to understand and therefore maintain [Hazan 1993]. The use of higher-order functions and laziness allows new levels of modularity to be attained [Hughes 1989] and the system has been designed in a highly modular fashion, making extensive use of abstract data types at all levels; this also contributes to the ease of maintenance and comprehension of the source code.

The scale of the implementation of the Chinese Tutor is large, with approximately 2000 lines of code (not including comments) in Miranda, distributed among the five models. There are 10 data files, of which the Chinese dictionary, equipped

with over 1000 Chinese words, is one. In addition, the Chinese Tutor uses a number of modules in the LOLITA system, increasing the total number of lines of code to around 4000. The LOLITA system is a Large-scale, Object-based, Linguistic Interactor, Translator and Analyser [Garigliano 1992] which has been developed at the University of Durham over the last 8 years.

The Chinese Tutor is robust because it can identify arbitrary transfer errors by using a general set of rules, and it does not fail when the input data deviates from what is expected. (For instance, if the student types in English when Chinese characters were expected.)

The Chinese Tutor is also largely domain-independent. It is possible to alter any part of the system with ease, and with very little disruption to other parts of the system. For instance, if tutoring systems for handling transfer in other languages are developed in the future, most of the Chinese Tutor, such as the general diagnostic heuristics and reasoning strategies for identifying the transfer errors, could be used without making many modifications.

The response of the Chinese Tutor is quick and within acceptable limits. It is capable of responding, within a few seconds, to the student's correct or incorrect input.

Practical Aspect

The *practical aspect*, i.e. the usability of the system by the potential users, has become an extremely important issue in the field of Intelligent Tutoring Systems (ITSs). This is because there is a widening gap between research in ITSs in the field of Artificial Intelligence (AI) and practical use of this technology by the educational community. Furthermore, the research in ITSs is becoming increasingly academic and unconnected to the practical aspects of teaching and learning [Murray 1991].

The Chinese Tutor is a practical system which has been designed to tackle a

real problem in second language learning using AI techniques. It is usable by the potential users mainly because of the following practical aspects of the system.

- The Chinese Tutor has been built to help English-speaking students (first-year students in the Department of East Asian Studies at the University of Durham in particular) to overcome the difficulties encountered in their grammar study. The overcoming of these errors will lead to an improvement in the standard of the students' Chinese.

- The linguistic knowledge of Chinese in the Chinese Tutor has been modelled according to that which has been taught in the students' first-year study of Chinese grammar. For instance, the Chinese dictionary includes all the words in the two text books used by the students.

- The Chinese Tutor has been built so that students should be able to use it with ease. For instance, no training should be needed for students to use the system.

Chapter 1

Methodological Introduction

Before we go into the more technical treatment of the problem of transfer in the chapters to follow, we first need to clarify some methodological issues in relation to the position of this research in the current field of research in AI. This is followed by a section on the criteria for success of this research, a section to explain controversial terminology, a section on the logical progression of the thesis and a section on how to read the thesis for specific information.

1.1 Scope of this Research

The purpose of discussing the scope of the research is to provide the reader with a better understanding of the topic of this research, thus eliminating the occurrence of misunderstandings.

This research lies in intelligent computer-aided/assisted language tutoring systems and focuses on tackling the following two issues: *first*, how to interpret what is occurring in the test papers that have been collected; and *second*, how to help students overcome common errors when they learn Chinese grammar.

1.1.1 Hypothesis of Transfer

This research has been started with a hypothesis that transfer is important as it is common among English-speaking students when they learn Chinese. This hypothesis is supported by views of experts on Chinese [see *Section 2.3*], views of experts on negative transfer [see *Section 2.1.1*] and personal teaching experience of Chinese.

Negative transfer is the use of a native language pattern or rule which leads to an error or inappropriate form in the target language. The term *negative transfer* is often used as a synonym for *mother tongue influence*, *the problem of transfer*, and *native language influence* in the field of second language acquisition. The above terms are used alternatively throughout the thesis. We must point here, however, when we use the term 'transfer' or 'negative transfer' etc, we are not making a linguistic point on how the transfer process actually happens in the mind, rather, we refer to the behaviour observed in the linguistic output of a learner, which can be interpreted as transfer.

1.1.2 Empirical Studies

Empirical studies can be used as a means of investigating whether the hypothesis of transfer is supported by the data. These studies can be undertaken by modelling the behaviour of students in a Chinese department. The data should be collected scientifically by following the procedures in the department. For instance, data can be collected through the standard tests given by the department on a regular basis to check how well their students have grasped certain aspects of Chinese.

There are two kinds of AI strategy. One is very close to Cognitive Science [see [Schank 1981]], the idea is that a system is (at some level of abstraction) using the same method (e.g. internal representation, or inferencing) as human beings do when they exhibit an 'intelligent' behaviour. While the other one simply tries to model human behaviour, with any means available, and without any duty (or claim)

for that to be similar to the way in which humans perform the task. The AI strategy adopted by this research is the latter, i.e. modelling human behaviour. Moreover, this research is neither about discovering how human beings really learn languages, nor how Chinese should be taught, which belong to the fields of linguistics, language teaching, psychology and cognitive science.

Empirical studies are needed because *first*, they can be used to reflect what actually happens in the field of language learning in a particular realistic context, i.e. what kind of help is required by students; and *second*, they can have impact on language learning, i.e. if a helpful tool has been designed based on these studies, it will probably be used by the students.

1.1.3 A Tool for Handling Transfer

A tool is needed to handle the problem of transfer as most of the errors identified in the test papers can be interpreted as transfer. In order to help students overcome errors of transfer more effectively than merely by doing exercises on their own, a general solution to the problem of transfer is required. The following is a list of elements which should be under consideration for the design of such a tool:

- The design of the tool should be based on the empirical data. For instance, if the data indicates that the majority of errors made by students are restricted to syntax, there will be little need to undertake semantic analysis on the student's input. In contrast, if semantic errors are very common among students, semantic analysis will be necessary.

- The error detection process needs to have a wide coverage of errors, including combinations of errors, using a general set of rules. It should not have a rule for specific errors (i.e. collecting a bug catalogue [see *Glossary*]). This is because when error anticipation functions correctly, it will focus the language learner's attention directly on the objective of the task. When an error made by a student does not match any specified errors in a bug catalogue, the

system will try to interpret the behaviour with some combination of other errors. It may totally misdiagnose the misconceptions of the student [VanLehn 1988]. The other drawbacks of the bug catalogue approach are: *firstly*, it is enormously time-consuming to provide a list of all likely errors, *secondly*, it is extremely difficult to provide a complete list of likely incorrect answers, even for the most experienced instructor [Pusack 1984], and *thirdly*, it is hard to expand these likely errors after they have been specified.

- The detection of types of error made by the students should be accurate. If a system cannot infer the type of error made, it will not be able to tell whether the student has made a critical error, thus making it hard to deliver appropriate help to the student.

- The tool should tailor its tutorial strategy to the advantage of the student. This is very hard to achieve because it is beyond the state of the art to tailor the strategies to the best advantage of the student [Ross 1987]. However, a tool which has a good knowledge of the student's past performance on the mastery of a particular kind of task will be able to tailor the instruction to the needs of the student better than a tool without such knowledge.

1.2 Criteria for Success of the Research

In order to help first-year students improve their standard of Chinese grammar, we first need to discover the difficulties encountered in their study. Once the difficulties have been identified, a general and practical solution should be obtained or devised. The success of a solution depends on how well the system detects common errors, and how effectively it can help students overcome these errors.

1.2.1 Difficulties in Learning Chinese

Empirical studies can be used as an important means of obtaining first-hand material on the difficulties encountered by students when they learn a second language such as Chinese. These studies should be undertaken in a general fashion. Issues which need to be considered include how the data should be collected; for how long the data collection should be taken place; and how many students should be involved.

The data can be collected by modelling what has already occurred in the field of language teaching such as classroom teaching, or standard tests provided by a department. The period of time for data collection must be long enough to cover the learning curve for learning a particular language up to a certain standard. The number of students being modelled must be large enough in order to make the data collection statistically meaningful.

1.2.2 A Solution to the Problem Identified

Once the problem of learning a particular language has been identified, a general solution should be proposed. For instance, a solution to the problem of transfer is considered general if a system can successfully pinpoint arbitrary transfer errors made by the students. A solution is constrained, however, if a system needs to specify some of these errors.

The following is a list of important principles that should be followed by the design of a general solution to a particular problem. These principles are: *scale*, *integration*, *flexibility*, *feasibility*, *robustness*, *maintainability* and *usability* [Smith 1994].

- **Scale** — the size of the system must be sufficient for realistic large-scale applications. Properties such as the size of the dictionary and the coverage of the grammar are critical.

- **Integration** — a system component (such as the Student Model) should be built so that it can be used to assist other components of the system (e.g. the Tutor Model).

- **Flexibility** — the system should have the ability to be modified for different tasks in different domains.

- **Feasibility** — this process incorporates making the system and its components efficient. For instance, the hardware on which applications run must not be too great and the execution speed must be acceptable.

- **Robustness** — a function of several factors such as the range of operating conditions and the acceptability of effects when the system is given invalid input. With regard to the first factor, a system with a wide range of permissible operating conditions is more robust than a system which is more restrictive. The second factor is the acceptability of effects and behaviour when the system is *not* used under permissible operating conditions [Schach 1990a].

- **Maintainability** — Historically, the term 'maintenance' has been applied to the process of changing a program after it has been delivered and is in use. These changes may involve simple modifications to correct code errors, more extensive modifications to correct design errors or drastic rewrites to correct specification errors or to accommodate new requirements [Sommerville 1992a]. Maintenance includes *corrective maintenance* (or *software repair*), i.e. the removal of residual faults, without changing the specifications, and *enhancement* (or *software update*) which includes changes to the specifications and the implementation of those changes. There are two kinds of enhancement: *perfective maintenance*, i.e. changes demanded by the user which will improve the effectiveness of the system such as additional functionality or decreased response time; and *adaptive maintenance*, i.e. changes made in response to changes in the environment in which the system operates [Schach 1990b]. A survey by Lientz and Swanson [Lientz 1980] indicates that about 17% of maintenance was corrective, 65% perfective and 18% adaptive.

- **Usability** — the system must meet the user's needs. The user may test, for example, how easy the system is to use and whether the system performs the necessary functions [Schach 1990a].

1.2.3 Evaluation of A System

There are no systematic evaluation procedures that have been used in ITSs [Kearsley 1987], [Shute 1993]. One way of evaluating a language tutoring system would be through a long-term study (a year, for instance) to test it on a completely random set of students taken from a large population of potential users of the system. After a learning period, the students would be tested in order that their ability could be assessed. The students would be divided into two groups of equal number, but with a mixed level of standards within each group. One group of students would be asked to use the system as a learning tool, while the other group would be provided with textbook exercises only, to be completed on their own. A comparative study (in the form of another test, for example) would be undertaken after the first set of students had used the system for a certain period of time. Unfortunately, this is beyond the scope of a Ph.D, as this kind of evaluation would prove time-consuming, and a single set of results may not be sufficient evidence to support ITS as an effective learning tool.

Another way of evaluating a system is short-term study on a number of potential users of the system. This method has been used by this research [see *Chapter 10*]. The short-term evaluation is preliminary in the sense that it cannot be used to prove that the Chinese Tutor is an effective learning tool. However, it is a step in the right direction, since the existing tools in the field of intelligent language tutoring are unable to carry out any kind of evaluation.

The short-term evaluation consists of three kinds of testing: system testing, user testing and expert testing. In system testing, the system must demonstrate that it can cope with the specially designed test cases. The results of this testing should show that the program does not crash, and therefore could be described

as being robust. In user testing, subjective feedback is needed from the potential users. In expert testing, subjective feedback from experts in education is needed. Questionnaires can be issued to both users and experts in order to establish what they think about the system, and its overall effectiveness as a learning tool.

1.3 Terminology Issues

The terminology issues will be handled by adopting the following scheme: the technical terms which are standard in the relevant literature are defined in the *Glossary*; technical terms created by a particular author are briefly explained in the text at their first mention, and also in the *Glossary* for reference; similarly for terms introduced by us which do not seem to be controversial. Finally, there are technical terms with no precise agreement in the community and terms introduced by us which might cause inappropriate understanding: they are discussed in the rest of this section.

Transfer

When we use the term 'transfer' or 'negative transfer', we are not making a linguistic point on how the transfer process actually happens in the mind, rather, we refer to the behaviour observed in the linguistic output of a learner, which can be interpreted as transfer.

Second Language Learning vs. Second Language Acquisition

Second language learning is sometimes contrasted with second language acquisition on the assumption that they involve different processes. The term 'learning' is used to indicate the conscious study of a second language, while the term 'acquisition' is used to refer to picking up a second language through exposure. Since there is no clear agreement among linguists on the above distinction of 'learning' and 'acqui-

sition', we will use both terms interchangeably, irrespective of whether conscious or subconscious processes are involved.

Mixed Grammar of Chinese and English

When we use the term 'mixed' in 'Mixed Grammar', we use it in the meaning of 'interwoven' rather than the more common meaning of the term 'mixed', i.e. blending into one mass. The Mixed Grammar of Chinese and English consists of a considerable number of rules, in which a Chinese rule is followed by a fragment of an English rule [see *Section 5.2*].

ITS vs. ICAI

Much of the research in the field of educational systems/software involving AI has been put under the name of 'ICAI', because of historical reasons. This acronym stands for 'Intelligent Computer-Aided/Assisted Instruction', a title developed from the name 'Computer-Aided/Assisted Instruction' (CAI), which is commonly given to the use of computers in education. More recently, the acronym 'ITSs' which stands for 'Intelligent Tutoring Systems' [Sleeman 1982b] is used. We prefer to use the latter acronym to distinguish instructional systems/tools involving AI from CAI.

Intelligent Language Tutoring Systems vs. Computer-Aided/Assisted Language Learning

There are two kinds of language tutoring systems: one has been developed by computer scientists using AI techniques, the other developed by educators without using AI techniques. The former is often referred to as 'Intelligent Language Tutoring Systems' (ILTSs) or 'Intelligent Computer-Aided/Assisted Language Learning' (ICALL), while the latter is used to refer to 'Computer-Aided/Assisted Language Learning/Instruction' (CALL or CALI). We will follow the above distinction. The

word 'intelligent' will be used wherever language instructional systems involving AI are indicated.

1.4 Logical Progression of the Thesis

The thesis is organised according to the following plan, in which every chapter performs a specific role and function.

The **Extended Abstract** plays the role of providing the reader with a brief overview of the whole research.

Chapter 1 addresses some important methodological issues in relation to the hypothesis of transfer, empirical studies, and a tool for handling transfer; followed by discussions on the criteria for success of the research; terminology issues; and finally how the thesis is organised and should be read for specific information.

Chapter 2 will explain how a practical problem, i.e. negative transfer in language learning, has been hypothesised. Issues in relation to empirical studies such as the reasons for and significance of empirical studies, the process of the data collection and data analysis, and most importantly, the results of the data analysis will be addressed in this chapter.

Chapter 3 will start by addressing some of the most important design and implementation issues in the field of Intelligent Tutoring Systems, gradually move to the areas of intelligent language tutoring, on which our research has been based and finally to intelligent language tutoring on negative transfer which is the core of this research. The capabilities and limitations of the Chinese Tutor in comparison with existing tools will be discussed in *Section 10.5.*

Chapter 4 will address our solution to the problem of transfer, which is the intelligent computer-based tutoring approach. The reasons for adopting this approach together with other decisions in relation to the design issues (such as the technique of Mixed Grammar, and the use of a natural language parser) will be

discussed. The overall structure of the Chinese Tutor will also be presented in this chapter.

Chapter 5 will introduce the Expert Model of the Chinese Tutor. We will first address the design of the Chinese dictionary, translation exercises, standard translations, additional exercises, and examples and explanations. We will then introduce the technique of Mixed Grammar in depth. The parsing strategy (i.e. how the student's performance is evaluated) will also be explained.

Chapter 6 will describe the tasks carried out by the Student Model and the Diagnoser. The tasks of the Student Model are to gather information on the current performance of the student; to keep a record of his/her learning history; and to update the student's record after each of the student's answers has been examined by the Diagnoser. The main task of the Diagnoser is to infer the types of error made by the student. The reason for discussing these two models in one chapter is that they are closely related.

Chapter 7 will explain the tasks of the Tutor Model which include planning student learning, making instructional decisions and selecting an appropriate tutorial strategy based on the student's performance.

Chapter 8 will discuss the Interface Module of the system, i.e. how the student interacts with the system. The Chinese window (i.e. CXTERM) and the help system will also be introduced in this chapter. Some examples of tutorial sessions used by the students will be shown at the end of this chapter.

Chapter 9 will concentrate on the General Implementation Issues of the Chinese Tutor including discussions on a list of important features of functional programming, and attributes possessed by the Chinese Tutor.

Chapter 10 will focus on the Evaluation of the system. The following issues related to evaluation are addressed in this chapter: the process of testing, techniques used in testing, the acceptance testing (testing by the potential users), and the expert testing (testing by human experts). At the end of the chapter, the

comparison between the Chinese Tutor and other existing tools will be carried out.

Chapter 11 will conclude the thesis by checking if the Chinese Tutor has met its criteria for success, and discussing what are some future research directions, and what the Chinese Tutor can offer students and teachers.

1.5 How Should the Thesis Be Read?

The purpose of this section is to save the reader's time of going through the whole thesis when only specific information is needed. In relation to the four aspects of the research discussed in the *Extended Abstract*, this section has been divided into four kinds of reading accordingly: the scientific reading, the technical reading, the engineering reading and the pragmatic reading.

1.5.1 Scientific Reading

For readers who are interested in the scientific aspect of this research, i.e. how the data was collected, how it was analysed and what the results of the data analysis were, please first refer to the *Criteria for Success of the Research* in the *Methodological Introduction*, and then Chapter 2, in which the empirical studies have been addressed in detail, and finally check the *Conclusions* to see if they have met the criteria for success.

1.5.2 Technical Reading

For readers who would like to read only the part of the thesis in relation to the technical aspect of the work, i.e. how the problem of transfer has been solved, please first read the related issues in the *Criteria for Success of the Research*, then *Chapter 4* for the outline of the solution, then move onto *Chapters 5–8* for detailed

discussions on the design of the system and finally check the *Conclusions* to see whether the solution to the problem is general and practical.

1.5.3 Engineering Reading

For those who are interested in the engineering aspect of the research, i.e. on how the system has been implemented, please read *Chapters 5–8* for the detailed design on the five models, followed by *Chapter 9* for the general implementation issues; *Chapter 10*, how the Chinese Tutor is evaluated; and finally check the *Conclusions* to see if it has met the criteria for success.

1.5.4 Pragmatic Reading

For readers who would like to know the pragmatic aspect of the research, i.e. how to use the Chinese Tutor, please first refer to the related issues in the *Criteria for Success of the Research*, followed by *Chapter 8* on interacting with the system together with the introduction of the help system, and finally to the *Conclusions*.

Chapter 2

Negative Transfer: A Practical Problem in Education

The results of the empirical studies undertaken as part of this research show that negative transfer appears to be a practical problem in students' learning of Chinese as a second language, because a vast majority of errors made by the students can be interpreted as transfer. These errors occurred at the structural level, at the phrasal level and at the lexical level. The main reason behind the empirical studies was that there was little evidence showing the causes of problems when English-speakers learn Chinese.

The results of our empirical studies agree with the views of experts on negative transfer [see *Section 2.1.1*] in second language learning. They are also in accordance with the views of experts on Chinese [see *Section 2.3*].

2.1 Why Were Empirical Studies Needed?

The reasons for carrying out our empirical studies were the following: *firstly*, the paucity of research data defining the problems English-speakers encountered when

learning Chinese; and *secondly*, the fact that linguists hold conflicting views as to the causes of students' problems in learning a second language.

There is no consensus among linguists on the major causes of learners' errors in second language learning. Some linguists suggest that negative transfer is an important factor in causing learners' problems. Some linguists are sceptical about the importance/existence of negative transfer and believe that developmental errors, i.e. errors found in the course of learning either a first or second language, are the most common errors among learners and they believe in the existence of language universals [see *Glossary*]. Some linguists suggest that transfer and universals interact in the acquisition of syntax.

2.1.1 Language Transfer

The awareness people may often have of language transfer is exemplified by their ability to identify a speaker's "foreign" accent — this is on the phonetic level, but the learner's syntax too can be affected by transfer. The role of negative transfer in the acquisition of syntax has been one of the most intractable of the many problems in second language research [Odlin 1990].

Odlin defines language transfer as: cross-linguistic influences resulting in errors, overproduction, underproduction, miscomprehension, and other effects that constitute a divergence between the behaviour of native and non-native speakers of a language.

He uses the following terms:

Underproduction: A learner tries to avoid producing examples of certain language structures, when these structures in the target language are very different from counterparts in the native language.

Overproduction: Overproduction is sometimes simply a consequence of underproduction. For example, in an effort to avoid Chinese relative clauses, En-

glish students may use too many simple sentences.

Miscomprehension: Native language structures can influence the understanding of target language messages. Miscomprehensions may also occur when native and target language word-order patterns differ.

Beginning in the post-war years and carrying on into the 1960s, there was a strong assumption that most of the difficulties in second language learning were due to the learners' L1 (first language or mother tongue). It was assumed that L1 could affect the learning of L2 (second language or target language), and the features of the L1 were transferred into the L2. The process of second language acquisition (SLA) was often interpreted as that of overcoming the effects of L1, of gradually replacing the features of the L1 that intruded into the L2 with those of the L2 and so of approximating ever closer to native-speaker speech. Corder [Corder 1978] referred to this view of SLA as a 'restructuring process'.

Linguists who believe negative transfer is an extremely important factor in causing learners' problems include Ringbom & Palmberg [Ringbom 1976]; Schachter & Rutherford [Schachter 1979]; Sheen [Sheen 1980]; Jansen, Lalleman, & Muysken [Jansen 1981]; Ard & Homburg [Ard 1983]; Andrews [Andrews 1984]; Appel [Appel 1984]; White [White 1985]; Schumann [Schumann 1986]; Singler [Singler 1988] and Odlin [Odlin 1989].

In order to discover the areas of difficulty, a procedure called 'contrastive analysis' (systematic comparison of two or more languages) was developed. This was established in the belief that it was possible to predict what difficulties the learner of a particular L2 would face, by comparing the learner's L1 with his/her L2.

It was not until the late 1960s that the contrastive analysis hypothesis was challenged in the following major aspects: *first*, there were doubts about the ability of contrastive analysis to predict errors; *second*, there were some theoretical criticisms regarding the feasibility of comparing languages; *third*, there were reservations about whether contrastive analysis was relevant to language learning [Ellis 1991a].

2.1.2 Language Universals

The empirical studies of the 1960s and 1970s contributed to scepticism about transfer in other important ways [Odlin 1989]. Much of the ongoing controversy over transfer was related to the ever-growing interest in language universals. The research suggested that second language acquisition was essentially no different from child language acquisition. The research also suggested that there were similarities in the developmental route followed by L2 learners with different L1. As a consequence, it was suggested that SLA followed a 'universal' route which was largely uninfluenced by such factors as the age of the learner, the context in which learning took place, or the learner's L1 background [Ellis 1991b].

For instance, the omission of *is* by learners of English in such cases as *"That very simple"* is an error made not only by Spanish speakers who learn English but also by speakers of Chinese, Japanese, and other languages [Huang 1978], [Itoh 1978]. In some cases the omission of *is* would be predicted from contrastive analysis, as in the case of omission of the copula (link verb) in *"That very simple"* by a Chinese speaker, which may seem to be clearly due to the difference in the grammatical systems of Chinese and English. However, the success of this contrastive prediction seems not to work on the omission of English copula forms by speakers of Spanish, Japanese and other languages that do have present-tense copulas [Odlin 1989]. Moreover, the transfer explanation for such errors seems questionable in the light of the fact that the omission of *is* and other copula forms also occurs in the speech of children learning English as their native language: for example, *"That a kitchen"* [Brown 1973].

For many linguists, such errors are nothing more than indicators of developmental processes found in both first and second language acquisition, and accordingly such errors are often termed *developmental errors* [Odlin 1989]. Linguists who belong to this school include Klima & Bellugi [Klima 1966]; Brown [Brown 1973]; de Villiers & de Villiers [de Villiers 1973]; Bailey, Madden & Krashen [Bailey 1974]; Fathman [Fathman 1975]; Hatch [Hatch 1978] and Van Patten [Van Patten 1984].

2.1.3 Transfer and Universals

The early research that sought to challenge the role of L1 in SLA [Dulay 1973] was conducted on the basis that an error was either the result of transfer or of some other factor such as developmental processing [Ellis 1991a]. Some linguists think that this is a naive view and they believe that transfer and universals can and do interact in the acquisition of syntax. They claim that any particular error may be the result of one factor on one occasion and another factor on another. There is no logical or psycholinguistic reason why a given error should have a single cause/interpretation. However, there is still no consensus about how much interaction there is or about the roles of transfer and universals (and other factors) as independent influences on acquisition [Odlin 1990]. Linguists who share the view that transfer and universals interact include Zobl [Zobl 1980] and Gass [Gass 1979].

2.1.4 Language Transfer Re-Examined

Despite the criticisms of contrastive analysis, there is a large and growing body of research that indicates that transfer is indeed a very significant factor in second language acquisition.

There were four remarkable developments of the contrastive analysis hypothesis. *First*, it was recognised that difficulties (the learner of a particular L2 would face) predicted by contrastive analysis might be seen as avoidance. *Second*, empirical evidence showed that interference was more likely to occur when there was some similarity between the L1 and the L2 items than when there was complete difference. *Third*, it was recognised that errors were a multi-factor phenomenon and that interference, as one of the factors, interacted in complex ways with other factors. *Finally*, the contrastive analysis hypothesis was incorporated into a cognitive framework by reinterpreting 'interference' as 'intercession', a strategy for communicating when there were insufficient L2 resources [Ellis 1991a].

2.2 Empirical Studies on Common Errors

Empirical studies were necessary in order to find the real problems encountered by students learning Chinese. The approach taken in the empirical studies was a practical one by collecting the data about the behaviour of first-year students.

2.2.1 Significance of Empirical Studies

Sleeman [Sleeman 1987] stresses that empirical studies are an important precursor to building an ITS — if one does not have a good knowledge of students' misunderstandings in a domain, it is not possible to produce an effective tutoring system.

The empirical studies that have been undertaken have provided us with crucial data on the common errors made by first-year students in learning the grammar of Chinese. Through these studies, we can discover which part of the Chinese grammar the students found easy to grasp and which part was difficult.

2.2.2 Data Collection

The empirical data was collected by monitoring the progress of first-year students learning Chinese grammar in the Department of East Asian Studies at the University of Durham. Data was collected between October 1991 and March 1992. The data collection was based on weekly tests given by the Department of East Asian Studies to their first-year students. The tests are used to routinely check how well the students have mastered the grammatical rules that they have been taught in a particular week.

Tests have been collected which cover all the lessons (55 lessons altogether) in *Modern Chinese Beginner's Course* I and II (edited by Beijing Language Institute in 1988) over the above period of time. These two volumes are used as textbooks

for first-year students.

The linguistic knowledge covered in each of the tests was based on the vocabulary and grammatical points from those two text books, that students had learned up to a certain period of time. Each week, the students were asked to do the standard tests designed by the teachers in the department. The standard tests were in the form of translation exercises, i.e. translating sentences from English into Chinese. The number of sentences for translation increased along with the experience of the students, to a maximum of 20 each week.

There were sixteen first-year students, of whom fifteen were native speakers of English. These students had no previous knowledge of Chinese, and were therefore representative of students that would be found on a first-year Chinese course at any university.

2.2.3 Data Analysis

The types of error in the test papers were classified in the data analysis. The numbers for each kind of error identified for that week were added together and finally the number of each kind of error was worked out as a percentage of the total number of errors.

The following main points were checked through the analysis of the data: *firstly*, what are the common errors made by the students; *secondly*, at which stage(s) of learning, do those errors appear; *thirdly*, what kinds of error are made by the students; and *finally*, whether the errors are restricted to syntax.

The classification of the types of error made by the students can be used as a means of revealing how serious an error is, and what kind of help can be provided to overcome it. There were six kinds of error identified in the students' test papers. These were syntactic transfer errors, phrasal transfer errors, lexical transfer errors, syntactic errors, lexical errors and errors of overgeneralisation. No distinction has been made between syntactic errors and phrasal errors, because the numbers of

both were so small. Both types of error are therefore included in the category of syntactic error. Examples of each kind of error is given after the definitions.

A syntactic transfer is an error which can be easily explained by using a native-language structure.

A phrasal transfer is an error which can be easily explained by using a phrase in the native language.

A lexical transfer is an error which can be explained by the direct translation of a word in the native language.

A syntactic error is an error which cannot easily be explained using a native-language rule or pattern.

A lexical error can be one of the following: a choice of a wrong character; a made-up character by the student; or an incomplete character.

Overgeneralisation, also known as over-extension, is a process common in both first and second language learning, in which a learner extends the use of a grammatical rule or linguistic item beyond its accepted uses.

Let us look at some examples of these errors taken from students' tests.

- A Translation of a Sentence from English into Chinese with a Syntactic Transfer Error.

  English Sentence:

  Anna reviews her Chinese grammar in the library.

  Student's Translation:

  安娜 复习 汉语 语法 在 图书馆 .

  Anna review Chinese grammar in library

  Comments: Most of the students may have translated the sentence according to the English word-order, which is incorrect in Chinese. A correct

Chinese translation should put the prepositional phrase *in the library* before the verb *review*.

Correct Translation:

安娜 在 图书馆 复习 汉语 语法.

Anna in library review Chinese grammar

- A Translation of a Sentence from English into Chinese with a Phrasal Transfer Error.

English Sentence:

Prof. Zhang cannot come with us to see the Chinese film.

Student's Translation:

教授 张 不 能 跟 我们 一起 去 看 中国 电影.

Prof. Zhang not can with us together go see Chinese film

Comments: A great number of students seem to have translated the phrase *Prof. Zhang* according to the English order (title + surname). In Chinese, however, a title (such as teacher or professor) normally follows a surname.

Correct Translation:

张 教授 不 能 跟 我们 一起 去 看 中国 电影.

Zhang Prof. not can with us together go see Chinese film

- A Translation of a Sentence from English into Chinese with a Lexical Transfer Error.

English Sentence:

I bought three books today.

Student's Translation:

我 今天 买 了 三 书.

I today buy particle three book

Comments: Many students have forgotten to use a measure word between the numeral (three) and the noun (book). This is because students may have referred to the structure of English rather than the structure of Chinese.

Correct Translation:

我 今天 买 了 三 本 书.

I today buy particle three measure word book

- A Translation of a Sentence from English into Chinese with a Syntactic Error.

English Sentence:

First-year students will go to China to study Chinese next year.

Student's Translation:

一 年级 的 学生 明年 学 汉语 去 中国.

first year of student next year learn Chinese go China

Comments: A few students made some pure syntactic errors when translating the sentence. By 'pure' syntactic errors, we mean errors which are not caused by the grammar of students' native language.

Correct Translation:

一 年级 的 学生 明年 去 中国 学 汉语.

first year of student next year go China learn Chinese

- A Translation of a Sentence from English into Chinese with a Lexical Error.

English Sentence:

John has finished his homework.

Student's Translation:

约翰 做 完 了 做业.

John do finish particle homework

Comments: Some students used a wrong character for the word *homework*, due to the confusion caused by words sharing the same pronunciation.

Correct Translation:

约 翰 做 完 了 作 业 .

John do finish particle homework

- A TRANSLATION OF A SENTENCE FROM ENGLISH INTO CHINESE WITH AN ERROR OF OVERGENERALISATION

English Sentence:

Are you going to have some black tea?

Student's Translation:

你 要 不 要 喝 几 个 红 茶 ?

you want not want drink some black tea

Comments: There are only a few students who translated the phrase *some black tea* by using a measure word before the noun phrase *black tea* which is not correct in Chinese. The error might be caused by students' over-extension of the use of measure words in Chinese.

Correct Translation:

你 要 不 要 喝 点 儿 红 茶 ?

you want not want drink some black tea

2.2.4 Results of the Analysed Data

The results of our analysis [see *Table 2.1 & 2.2*] indicate that the errors which can be explained by reference to negative transfer make up 78% of the errors committed by the students. This is made up of syntactic transfer errors (42%), phrasal transfer errors (20%) and lexical transfer errors (16%). From the results one can see that syntactic transfer appears to be a significant factor in hindering the students' learning of Chinese grammar.

NO. OF LESSONS	5-8	9-11	12-15	16-18	19-21	22-25	26-28
NO. OF SENTENCES	10	12	12	13	13	14	15
NO. OF STUDENTS	13	14	12	12	12	13	12
TEST DATE (1991)	28/10	4/11	11/11	18/11	25/11	2/12	9/12
NO. OF SYNTACTIC TRANSFER	14 40%	136 65%	82 61%	63 48%	53 51%	49 45%	36 33%
NO. OF PHRASAL TRANSFER	5 14%	22 11%	25 19%	23 18%	15 14%	18 17%	34 31%
NO. OF LEXICAL TRANSFER	8 23%	20 10%	2 1%	8 6%	4 4%	9 8%	15 14%
TOTAL TRANSFER ERRORS	27 77%	178 86%	109 81%	94 72%	72 69%	76 70%	85 79%
NO. OF SYNTACTIC ERRORS	2 6%	4 2%	10 7%	7 5%	2 2%	4 4%	9 8%
NO. OF LEXICAL ERRORS	6 17%	26 12%	11 8%	18 14%	5 5%	15 14%	12 11%
NO. OF OVER-GENERALISATIONS	0	0	5 4%	12 9%	25 24%	13 12%	2 2%
TOTAL OTHER ERRORS	8 23%	30 14%	26 19%	37 28%	32 31%	32 30%	23 21%
TOTAL ERRORS	35	208	135	131	104	108	108
NO. OF SENTENCES NOT TRANSLATED	0	4	1	6	6	2	0

Table 2.1: Results of the Analysed Data (Part 1)

NO. OF LESSONS	29-33	34-36	37-39	40-42	43-45	46-48	49-51	52-55	*TOTAL*
NO. OF SENTENCES	17	17	18	19	19	17	20	20	
NO. OF STUDENTS	13	12	11	11	12	12	12	12	
TEST DATE (1992)	27/1	3/2	10/2	17/2	24/2	2/3	9/3	16/3	
NO. OF SYNTACTIC	53	31	55	58	82	44	24	24	804
TRANSFER	33%	32%	44%	45%	46%	23%	18%	28%	42%
NO. OF PHRASAL	43	26	13	29	28	58	38	12	389
TRANSFER	27%	27%	10%	22%	16%	30%	28%	14%	20%
NO. OF LEXICAL	32	19	33	22	38	40	39	24	313
TRANSFER	20%	20%	26%	17%	21%	21%	29%	28%	16%
TOTAL TRANSFER	128	76	101	109	148	142	101	60	1506
ERRORS	81%	79%	81%	84%	83%	74%	75%	69%	78%
NO. OF SYNTACTIC	9	6	7	8	5	3	4	2	82
ERRORS	6%	6%	6%	6%	3%	2%	3%	2%	4%
NO. OF LEXICAL	9	11	7	10	5	7	5	0	147
ERRORS	6%	11%	6%	8%	3%	4%	4%		8%
NO. OF OVER-	13	3	10	3	20	39	25	25	195
GENERALISATIONS	8%	3%	8%	2%	11%	20%	19%	29%	10%
TOTAL OTHER	31	20	24	21	30	49	34	27	424
ERRORS	19%	21%	19%	16%	17%	26%	25%	31%	22%
TOTAL ERRORS	159	96	125	130	178	191	135	87	1930
NO. OF SENTENCES	20	11	5	11	18	5	0	2	91
NOT TRANSLATED									

Table 2.2: Results of the Analysed Data (Part 2): The Values in the Total Column Are Calculated from the Entries of Tables 2.1 & 2.2

The most common syntactic transfer errors made by students appear to be those relating to the word-order within a sentence: English sentence structure being different to Chinese. Phrasal transfer errors are also common among students. This kind of error often occurs inside noun phrases. Lexical transfer errors seem to be caused by the direct translation of a word from English which is either absent or incomplete in Chinese.

Only 22% other errors are not classed as negative transfer errors, of which syntactic errors form 4%, lexical errors 8% and errors of overgeneralisation 10%. There is a fuzzy boundary between negative transfer and overgeneralisation, therefore, some of the overgeneralisation errors may be caused by negative transfer. For instance, in English the same verb is used in phrases like "wear a jumper" or "wear glasses". In Chinese, however, two different verbs 穿 and 戴 are used depending on the nouns followed. The verb 穿 is required when the noun followed represents "clothing", while 戴 is used when the noun indicates "gloves, glasses, jewellery etc". So if the student produces 穿手套 ("wear gloves", but with the wrong verb), it can be interpreted either as a transfer error or an overgeneralisation error, depending on whether he/she referred to the usage of the verb "wear" in English or tried to extend the usage of the verb 穿 in Chinese. Thus, we could count some of the overgeneralisation errors as being negative transfer, which would make the percentage of negative transfer errors even higher.

The results of the empirical studies also indicate that some of the most important grammatical points in Chinese grammar have caused a considerable number of problems to the students. For instance, 46% of the errors can be interpreted as syntactic transfer errors when the students learned the usage of the 把 (a preposition with no English equivalent) construction in lessons 43–45. The students may have translated this type of sentence according to the English word order where the 把 construction must be used in Chinese. For instance, in English one can say "He will put his books on the shelf", but in Chinese, a 把 construction must be used when the coverb 在 (be in/at a place) takes an object of location and acts as the complement of the result for the predicate 放 (put), showing where the person

or thing is as the result of the action of the verb. A coverb is a word which can be used either as a preposition or a verb. A correct way of translating the sentence into Chinese should follow this structure: he + 把 clothes + put + on bed top.The phrase "on ... top" is a split up preposition in Chinese.

We must point out, however, that among the transfer errors in our data, some may also be developmental errors. An interesting suggestion of how "double determined" errors can occur has been made by Cazden [Cazden 1975] *et al.* Our research has been concentrated on English-speaking students learning Chinese. How Chinese children learn Chinese or how people of other nationalities learn Chinese are interesting issues but beyond the scope of this Ph.D and a Ph.D topic in their own right.

The results of our empirical studies agree with the views of experts on negative transfer in second language learning. They also accord with the views of experts on Chinese grammar.

2.3 Views of Chinese Experts on Negative Transfer

The results of the empirical studies are compatible with the views of experts on Chinese. These experts are from the Oriental Faculty at Cambridge, the Oriental Institute at Oxford, the Department of East Asian Studies at the University of Leeds, the Department of East Asian Studies at the University of Durham, and Prof. T. Jin and Prof. G. Yin. They are professors in Chinese at China Renmin University in Beijing. They were teaching Chinese in the Department of East Asian Studies at the University of Durham from 1990 to 1992.

An approach that was used, as part of this research, was to elicit knowledge from human experts on the Chinese language. In AI, this method is known as *knowledge acquisition.* A questionnaire [see *Appendix A*] was issued in October

1991 and distributed to the experts in the above universities. Replies were received from 16 experts.

The questionnaire was focused mainly on the following two aspects: *firstly*, what are the common errors observed by the experts among their first-year students; *secondly*, what tutorial techniques do they use in helping the students solve these problems. The second point will be discussed in *Section 7.1.*

According to the results of the questionnaire [see *Appendix B*], the experts "guesstimated" that when students learn Chinese grammar, they use approximately 70% of the grammar of their native language. These experts believe that negative transfer is *fairly* important in first-year students' learning of Chinese and that 74% of the work of their first-year students is affected by negative transfer. This "guesstimate" of 74% by the experts on the influence of negative transfer on their students is very close to the percentage of errors in the empirical studies which can be interpreted as transfer errors (78%).

Chapter 3

Related Research

Over the last decade, Artificial Intelligence has emerged from the research laboratories and become an important component in many areas of high-technology development. For instance, AI is used in: computer-aided design, computer-integrated manufacturing, speech understanding, computer vision and expert problem-solving systems [see *Glossary*]. These are only a few of the many ways in which AI has been applied to solving problems in high-technology areas. AI is defined as: "... the field of research concerned with making machines perform tasks which are generally thought of as requiring human intelligence" [Beardon 1989].

In addition to the application areas mentioned above, AI has been applied in the field of education, with the result often referred to as Intelligent Tutoring Systems (ITSs).

The application of AI principles to instruction has concentrated on the following aspects: student knowledge (what the student does and does not know), expert knowledge and instructional principles [Lesgold 1990].

In this chapter, we start the discussion with some of the most important design and implementation issues in the field of ITSs, then move on to the area of intelligent language tutoring by analysing the capabilities and limitations of existing

language tutoring tools, and end the chapter by discussing language tutoring on negative transfer which forms the core of this research.

3.1 Intelligent Tutoring Systems

An Intelligent Tutoring System is a computer program that uses AI techniques for representing knowledge and undertaking an interaction with a student [Sleeman 1982b].

Intelligent Tutoring Systems have taken on many forms, but fundamentally they have separated out the major components of a tutoring system in a way that allows both the student and the system flexibility in the learning environment that closely resembles what actually occurs when student and teacher sit down one-on-one and attempt to teach and learn together. As in any other tutoring system, the components represent the content to be taught, a mechanism for understanding what the student does and does not know, and tutorial strategies [Park 1987]. In ITSs, these components are referred to respectively as the problem-solving or expert model, the student model and the tutor model.

In this section, the differences between the ITSs and the conventional Computer Aided Instruction (CAI) systems are addressed, followed by a brief introduction to some of the representative ITSs, and finally the design and implementation issues of ITSs.

3.1.1 Differences between Conventional CAI and ITSs

The term 'conventional Computer-Aided Instruction systems' (conventional CAI systems) is adopted to distinguish them from 'intelligent tutors' i.e. ITSs. The former are tutoring systems which have been designed by educational researchers or training developers without using AI techniques.

ITS is fundamentally different from conventional CAI in terms of the basic philosophies underlying the structures and development processes of the systems. ITS has been developed from the field of computer science (particularly AI), while conventional CAI stems from instructional psychology or technology. Conventional CAI and ITS differ mainly in the following aspects [Park 1987]:

- Conventional CAI has been developed by educational researchers and training developers to solve their practical problems using computer technology. By contrast, ITS has been designed primarily by computer scientists to explore the uses of AI techniques in the processes of learning and teaching. Thus, ITS projects focus on the technical aspects of the system (e.g. knowledge representation techniques, natural language processing techniques, inferencing mechanisms [see *Glossary*] etc.) rather than on instructional or domain features.
- In most conventional CAI systems, the instructional components (i.e. subject matter, student information and tutorial strategy) are stored and implemented in a single structure. Although some systems have separated the instructional components, their operational procedures are still predefined. This style is called '*ad hoc*, frame-oriented' CAI [Carbonell 1970]. In contrast to this, ITS has separated the instructional components into individual models and the tutoring process is tailored to the needs of the student.
- In conventional CAI systems, task analysis is used to identify tasks and subtasks to be taught and the content elements required to learn the tasks. In ITSs, the AI knowledge representation techniques are used to organise knowledge (including the subtasks and content elements) into a data structure for manipulation.
- Most of the instructional strategies in the early forms of conventional CAI were determined from binary judgements on the student's responses (correct or incorrect). Later on methods of student modelling were improved by using quantitative procedures. The quantitative information

is used to model the student's learning and to choose instructional treatments. The methods of student modelling in ITSs happen to be qualitative, i.e. an inferencing mechanism is used to assess the student's performance from the analysis of his/her responses.

- The success of conventional CAI systems is determined by the degree of their instructional effectiveness and efficiency. Different evaluation methods (such as pilot tests [see *Glossary*]) are applied to assure this effectiveness and efficiency. By contrast, no systematic evaluation procedures have been used in ITSs to assure the quality of the system during the development process or to validate its success after development. People until now, seem to determine the success of an ITS by its ability to deal with special processes in instruction (e.g. inferencing mechanism).

3.1.2 Examples of ITSs

Almost all research undertaken in ITS has been in the context of specific programs designed for a particular subject domain [Kearsley 1990]. *Table 3.1* lists some of these programs:

Carbonell's [Carbonell 1970] **SCHOLAR** for teaching the geography of South America is the pioneering ITS. The subject matter of SCHOLAR is represented in a semantic network of facts, concepts and procedures. This makes it possible to change the teaching subject with only minor changes to the executive program [Geller 1990]. SCHOLAR's student model constitutes an early version of what has been called the 'overlay' method [see *Section 3.1.3*]. However, the diagnostic process taking place in SCHOLAR is not complex. SCHOLAR's tutorial strategies are fairly primitive, consisting mainly of local topic selections. For instance, the student is allowed to ask vague questions such as "Tell me something about Peru" [Wenger 1987c].

SYSTEM	SUBJECT AREA	REFERENCE
SCHOLAR	Geography of South America	Carbonell 1970
WHY	Meteorology	Stevens 1977
BUGGY	Elementary Arithmetic	Brown 1978
WEST	Arithmetic Game	Brown 1979
EXCHECK	Axiomatically-based Mathematics	Suppes 1981
SOPHIE	Electronic Troubleshooting	Brown 1982
GUIDON	Medical Diagnosis	Clancey 1983

Table 3.1: Examples of ITSs

SCHOLAR is extended by the **WHY** system, an experimental Socratic tutoring system for rainfall processes developed by Stevens and Collins [Stevens 1977]. In this system, the domain knowledge is no longer contained in a semantic net, but in a hierarchy of scripts that represent stereotypical sequences of events [Wenger 1987c]. A script is a structure used to organise knowledge about stereotypical situations such as dining at a restaurant, going to the movies etc. WHY focuses on identifying the misconceptions exhibited by students and using corresponding tutorial strategies. There are two weaknesses [Wenger 1987c] of the system WHY. *First*, the global tutorial goals often pursued by human tutors, such as the correction of a pervasive misconception, are ignored in the local applicability conditions of the rules. *Second*, the script-based representation is not really sufficient either to explain the mechanisms involved in the rainfall process or to diagnose and correct the student's misconceptions.

BUGGY, developed by Brown and Burton [Brown 1978], attempts to diagnose the student's errors ('bugs') by observing his/her answers on a set of simple addition problems [Bregar 1980]. An interesting aspect of BUGGY is that it could be used to give teachers practice in diagnosing students' errors by generating problems with known bugs to be identified [Kearsley 1990].

WEST, also developed by Burton and Brown [Burton 1982], is a computer

board game which requires the player-student to use arithmetic skills in an optional manner in order to win. WEST is one of the first attempts in implementing a tutorial strategy. This kind of tutorial strategy in ITSs is used to identify when the student should be interrupted and what specific advice should be given.

EXCHECK, developed by Suppes [Suppes 1981] and his associates [Blaine 1977] is a proof checker. There is no student model in EXCHECK; however, its inference procedures in the expert model can make assumptions about the student's reasoning and track his/her solutions, thus providing a 'reactive environment' similar to that of SOPHIE [Park 1987].

SOPHIE is a tutoring system for electronics troubleshooting developed by Brown, Burton and colleagues [Brown 1982]. SOPHIE analyses the student's hypotheses and determines the consistency of their arguments. An important feature of their system is a natural language interface within its restricted discourse domain [Bregar 1980].

GUIDON, developed by Clancey and colleagues [Clancey 1983], is a major milestone in ITSs because it is the first tutor designed to work with an already existing expert system (MYCIN). MYCIN is a computer-based medical consultation system for diagnosing infectious diseases. GUIDON teaches the diagnostic rules which exist in MYCIN, but it suffers from the limitation that if a student followed a diagnostic strategy different from MYCIN's top-down search through the hierarchy of disease, GUIDON would reject reasonable hypotheses [Wenger 1987e].

3.1.3 Design Issues of ITSs

The object of learning is knowledge or expertise in some domain. Ideally, an ITS should contain primarily three models: the expert model, the student model and the tutor model. These models represent the three main components of any didactic system, namely the content to be taught, a mechanism for understanding what students do and do not know, and the tutorial strategies.

Expert Modelling

The 'expert' component of an ITS has the task of generating problems and evaluating the correctness of the student's solutions. Because of this, the domain knowledge should be organised in a way which allows its data to be flexibly manipulated in the teaching and learning process. The following are some representative AI methods used in organising the domain knowledge: development of semantic networks, application of production systems, procedural systems and building of scripts [Park 1987].

Semantic networks contain all the factual information required for teaching the knowledge in a large database. A network is constructed by nodes representing objects, concepts and situations in the domain knowledge, and links between nodes, representing their relationships. This method is based on psychological models of human associative memory [Norman 1975], [Quillian 1968].

Production systems are used to build modular representations of skills and problem-solving methods. The knowledge database consists of rules, called productions, in the form of condition-action pairs, such as 'If <this> condition occurs, then do <this> action'. Production systems were developed by Newell and Simon [Newell 1972] for their models of human cognition.

Procedural systems require the student to learn the subskills in order to acquire a complete skill in a well-specified situation. Procedural systems stress explicit control of the process of using knowledge, or problem-solving.

Scripts are data structures containing declarative and procedural information in predefined internal relations. A script for generic knowledge has specific knowledge slots for facts that are typically known about the generic knowledge as well as attached procedures used to determine the specific nature of facts. Script structures have been developed by Schank and Abelson [Schank 1977] to represent sequences of events on the basis of Minsky's work [Minsky 1975].

Student Modelling

In ITSs, one of the aims of the student model, a model which represents the student's knowledge structure, is a justification of the tutoring strategy [Matsuda 1992]. The task of a student model in ITSs is to collect relevant information about the performance of a particular student that can be used to guide the behaviour of an ITS. The purpose of a student model is to provide the system with information about the student's knowledge and skills, whether correct or incorrect, so that the system can diagnose the type of error if a mistake has been made, suggest appropriate solutions, plan the student's learning and tailor short-term decisions about what to do and say next to the advantage of the student.

There are different approaches to student modelling due to the complexity of the problem. Kearsley [Kearsley 1990] pointed out that most student models have been of the 'overlay' type (e.g. WUSOR [Carr 1977], SCHOLAR), that is a checklist indicating which of the procedural components of the expert model have been matched by the student [Lesgold 1990]. A student model, therefore, consists of the expert model in addition to a list of items that are missing. A variant of overlay modelling puts weight on each element in the expert knowledge base [VanLehn 1988]; for example, 1 indicates mastery, -1 indicates ignorance, and 0.5 indicates partial mastery. In overlay models, the student knows a subset of what a domain expert knows. Learning is the process of acquiring consecutively a more complete subset of the expert's knowledge units.

Other approaches to student modelling include bug models (or libraries), register models, procedural models and pattern-matching models [Fischetti 1992].

The student's misconceptions (bugs) in the bug models are represented by malrules as deviations from correct skills (e.g. BUGGY, SOPHIE). The bug model employs a library of predefined mistakes or misconceptions which a student may have and which need to be unlearned or replaced by correct conceptions and skills. A student model consists of an expert model in addition to a list of bugs. This bug library or bug catalogue technique is the second most common kind of student

modelling system. BUGGY is a good example of such a model, and identifies over 100 consistent but faulty procedures used by different students in arithmetic subtraction [Duchastel 1989]. Assembling the library is the biggest hurdle in the bug library approach, the drawbacks of which have been discussed in *Section 1.1.3.*

The student's knowledge in register models is represented by a set of parameters which are given values during the tutorial activity. In procedural models, a program is used to simulate the student's behaviour and develop hypotheses about his/her performance. In pattern-matching models, the student's knowledge is monitored through pattern-matching which flags the topics that have been mastered by the student.

Tutor Modelling

The prime objective of an ITS is to provide adaptive instruction to an individual student [Khuwaja 1992]. A tutor model is used to select a task for the student, monitor his/her performance, provide assistance and select remedial material. There is a growing interest in computational models of didactics, although the topic remains largely neglected. One of the reasons for this neglect is the fact that human teachers' expertise is very complex, and its constituents are little understood [Wenger 1987d]. In existing ITSs, two major kinds of instructional method have been explored: the Socratic method and the coaching method.

The Socratic method guides students through the process of debugging their own misconceptions by asking successive questions [Carbonell 1970], [Stevens 1979]. In the debugging process, students are assumed to reason about what they know or do not know, and therefore to modify their conceptions [Park 1987]. One system which implements the Socratic method is WHY.

The coaching method provides students with an environment in which to engage in activities such as computer games in order to encourage skill acquisition and general problem-solving abilities. The goal of such a method is to have students enjoy and learn as a consequence [Burton 1982], [Goldstein 1982]. A system that

uses the coaching method is WEST.

3.1.4 Implementation Issues of ITSs

ITS research is still primarily at the prototype stage [Fischetti 1992]. Before ITSs can enter the mainstream of the education and training world, there are three major issues that need consideration: the practical aspect, the accessibility of ITSs and performance factors.

Practical Aspect of ITSs

As research in ITSs continues to produce more sophisticated systems, the gap between the AI community and the educational community continues to widen. The ITS research is becoming increasingly academic and unconnected to the pragmatic aspects of teaching and learning [Murray 1991]. One of the causes of this gap may be the over-emphasis on the technical aspects of the system, i.e. exploring various AI techniques.

Accessibility of ITSs

One important reason for preventing ITSs from becoming more widespread is the labour-intensive nature of the development of these systems. The amount of time and effort required to design an ITS which teaches even a small amount of content is still enormous, often in the order of many person-years.

Another development required for ITSs to become more widespread in the short-term, is the availability of ITSs in a greater variety of content domains [Kearsley 1990]. Most ITSs have been restricted to the highly-structured content areas such as mathematics, electronics and games. Carbonell's geography lesson demonstrates that this need not be the case. ITSs need to be developed in other content domains as well such as language tutoring.

Greater availability of ITSs is also needed [Kearsley 1990]. It is hard for designers and programmers to understand the nature of ITSs unless they are able to examine and use such programs. Access to ITSs is usually limited to those who are immediately involved in the development of such a system. At present, there are no ITSs commercially available for personal computers.

Performance Factors of ITSs

ITSs, like most AI systems, tend to be very computationally complex and require enormous amounts of memory [Kearsley 1990]. Most of the machines for AI applications are too expensive at present to be widely used in schools or training centres.

3.2 Intelligent Language Tutoring

One of the limitations of ITSs that has been discussed in *Section 3.1.4* is that the development of most ITSs has been restricted to highly-structured content areas. Intelligent language tutoring is one of the subfields of ITSs which has been underdeveloped, because of the complexity of language tutoring.

Intelligent Language Tutoring Systems (ILTSs), like mathematical or medical diagnosis systems in ITSs, also consist of three main components: an expert model which contains all the linguistic knowledge for tutoring and a parser for evaluating the student's responses; a student model which infers the current state of learning of a student; and a tutor model which selects an appropriate tutorial strategy according to the performance of the student. However, the methods used in organising each model in ILTSs do not necessarily have to be the same as in other ITSs. For instance, the overlay student modelling, the coaching and Socratic tutorial strategies used in other ITSs, may not be necessary or suitable methods in language tutoring.

Intelligent language tutoring refers to tools designed using AI techniques for handling problems in connection with a language or languages. These tools are different from computer-assisted/aided language learning (CALL), a subfield of conventional CAI [see *Section 3.1.1*], developed by educators without using AI techniques.

The tools under the term *intelligent language tutoring* include research and development for language tutoring, which can be either an intelligent language tutoring system/tool/prototype or a partial tutoring system (e.g. an error detector and/or corrector). The reason for including the partial tutoring tools is that there are hardly any ILTSs, since most of the current research focuses primarily on the development of certain aspect(s) of a language tutoring system.

In this section, the capabilities and limitations of the eight existing tools in intelligent language tutoring will be examined, followed by detailed discussions on issues of negative transfer, i.e. the limitations of the existing tools in handling transfer, and finally, a summary of the limitations of the existing tools in language tutoring will be presented. The Chinese Tutor will not be compared with the related work in this section, since it has not been formally introduced yet. The capabilities and limitations of the Chinese Tutor in comparison with the existing tools will be discussed in *Section 10.5*.

3.2.1 Capabilities and Limitations of Existing Language Tools

The capabilities and limitations of existing language tools will be examined from two aspects: the practical aspect, i.e. in relation to practical problems in language learning in education, and the technical aspect, under which some important features of language tutoring will be discussed. Before the detailed study of the eight current tools, a brief introduction to each of them will be given.

Eight Existing Language Tools

There is a growing interest in the design and implementation of a language tool which undertakes grammatical diagnosis. However, there are still not many systems available which can provide the student with a successful tutorial session on his/her grammar learning. This is probably due to the complexity of language tutoring. There are eight existing tools that we are aware of, among which only two tools (XTRA-TE and Schwind's ILTS) are 'complete' in the sense that they contain most of the key technical features which any sophisticated language tutoring system should exhibit. The following is a brief introduction to the existing tools, which have been listed according to the date of their release.

FGA: The French Grammar Analyser

The French Grammar Analyser (FGA) of Barchan, Woodmansee and Yazdani [Barchan 1986] is a Prolog-based analyser for French input typed in by a student. FGA is based on the earlier tool of Imlah and du Boulay's [Imlah 1985] French RObust Grammar checker (FROG).

VP^2: the Role of Native Grammars in Correcting Errors in Second Language Learning

VP^2, developed by Schuster [Schuster 1986] is a Prolog-based tool for helping Spanish students to grasp the use of English verb-particle and verb-prepositional phrase constructions. VP^2 presents the student with exercises in Spanish and asks him/her to translate them into English.

Scripsi: an Intelligent Error Diagnoser

Scripsi, developed by Catt [Catt 1988] is a Prolog-based syntactic error detector. It analyses the English input typed in by native speakers of French or Chinese and

detects transfer and overgeneralisation errors.

ALICE: Acquisitions of Linguistic Items in the Context of Examples

ALICE, developed by Cerri and colleagues [Cerri 1989] is a tool for helping students master the use of subordinate conjunctions in English, French and Italian by providing the student with a cloze test [see *Glossary*].

XTRA-TE: Using Natural Language Processing Software to Develop an ITS for Language Learning

XTRA-TE, developed by Chen and Kurtz [Chen 1989] is a Prolog-based tool for teaching English to native speakers of Chinese. XTRA-TE is based on XTRA (English Chinese Sentence TRAnslator), developed by Huang [Huang 1987] and extended to Teach English (-TE) to native Chinese speakers.

Schwind's ILTS: an Intelligent Language Tutoring System

The Intelligent Language Tutoring System (Schwind's ILTS) developed by Schwind [Schwind 1990] is a Prolog-based system for teaching German to native speakers of French.

eL: Using AI in CALL

eL (inference engine), developed by O'Brien [O'Brien 1992] is a Prolog-based syntactic error corrector which operates by taking an English input from a learner and checking its grammatical correctness. eL was developed on the basis of a previous tool, LINGER (Language INdependent Grammatical Error Reporter), developed by Barchan [Barchan 1987].

A Grammar Detector and Corrector (referred to as GDC for the rest of this thesis, for convenience of discussion)

GDC, developed by Aiello, Sanctis and Micarelli [Aiello 1993] is a Lisp-based tool for detecting syntactic errors in the English input typed in by a student.

Practical Aspect

One of the major limitations of current ITSs is the lack of proven educational value: they are not designed according to instructional needs. An effective ILTS, we believe, should be able to deal with a real problem in the field of language learning. It is of great importance for an ILTS to have a good knowledge of the needs required by students in second language learning in order to provide fruitful tutorials which can be tailored to the benefit of the student. A crucial means of discovering the student's needs in a domain is by empirical studies. Sleeman [Sleeman 1987] stresses that empirical studies are an important precursor to building an Intelligent Tutoring System.

To the best of our knowledge, there has not been any ILTS designed on the basis of empirical data or first-hand materials for tackling a *practical* problem in second language learning.

Technical Aspect

One thing that should be pointed out at the beginning of this section is that the designers of the eight existing tools mentioned above have been contacted, but so far, they have not replied. The reason for contacting these designers was that we tried to get more technical details on the design and implementation of their tools and tried to see if it is possible to run their systems. As these systems are not in the public domain, we have been unable to carry out more detailed investigation.

In this section, some of the most important technical features in intelligent lan-

guage tutoring will be addressed by examining the relevant features in the existing tools. Each of the technical features will be presented in turn. In cases where information was not available for a particular tool it will not be discussed under the corresponding technical feature, since the published papers did not all enter into the technical details of their implementations, e.g. detailed design or essential parameters such as the size of its grammar. The features that need to be considered are:

1. Grammatical Coverage
2. Range of Errors Diagnosed
3. Grammar Diagnosis
4. Current State of Learning
5. Updating of Student Model
6. Tutorial Plans
7. Tutorial Strategies

Technical features such as learning environment, the correctness of input, ambiguous cases and testing by students, will be shown together with the above seven features in *Tables 3.2 & 3.3* at the end of this chapter.

1. Grammatical Coverage

Grammatical coverage refers to the size of a grammar which can be *limited*, *medium* or *large*, depending on how many grammatical rules are contained in a grammar and how large the grammar coverage of a particular language is. Grammars which contain less than 100 rules and model only some specific areas of a language such as noun phrase or verb phrase, are considered *limited*. Grammars which consist of 350 rules or more and can handle any kind of free-form input are *large*. Other grammars are classified as *medium*.

The grammatical coverage of FGA is not specified, however the designers have pointed out that only a subset grammar and dictionary for French is available.

VP^2's grammatical coverage focuses on English and Spanish verbal constructions formed from a verb in addition to a particle or a prepositional phrase.

The grammatical coverage of Scripsi is unspecified, however from the designer's description of the components of its grammar of English, its coverage is by no means large. There are three major components in Scripsi's grammar: lexicon (words and morphological rules), phrase structure rules (grammatical agreement, e.g. this book) and transformational rules which in this system, as the designer has pointed out, cover only subject-auxiliary inversions. Scripsi does not explain how the grammars of Chinese or French are designed or how large the grammars are.

ALICE's grammar focuses on the differences of subordinate conjunctions in English, French and Italian.

XTRA-TE's grammatical coverage, according to its designers, contains approximately 500 grammatical rules and is *very large.* (The relative size of the English and Chinese grammars are not specified).

The size of the grammar of Schwind's ILTS is unspecified. However, its designer points out that the system knows a subset of the language to be taught (German).

The grammatical coverage of eL is not specified, nor has it been specified in LINGER, on which eL is built.

GDC is composed of 124 grammatical rules and the size of the grammar is therefore reasonable, i.e. *medium.*

The grammatical coverage of the Chinese Tutor will be addressed in *Section 5.2.*

2. Range of Errors Diagnosed

Range of errors diagnosed refers to the possible types of error that can be detected by a particular tool. If a tool can cope with a wide range of errors (i.e. is not restricted to only a few grammatical points in a language, such as subject-verb agreements or the use of articles etc.), it will be considered as more general than tools which only deal with certain kinds of (simple) error.

The types of error that can be detected by FGA, according to its designers, are the following, which are quite restricted:

- surface-level lexical errors (e.g. *le homme* instead of *l'homme*)
- word disagreements (e.g. *the boys kicks*)
- the misplacement of pronouns (pronouns outside negative clauses such as *Il n'y a pas quelqu'un* instead of *Il n'y a personne*)
- assumed misspellings (e.g. *garcon* instead of *garçon*)

The following types of transfer error, restricted to verbs plus particles or prepositions, can be detected by VP^2:

- missing particle (e.g. *put* instead of *put on*)
- incorrect preposition (e.g. *think* instead of *think about/of*)
- additional preposition (e.g. *saw with Jon* rather than *saw Jon*)

Scripsi can cope with the following types of transfer and overgeneralisation error.

Areas of language transfer:

- phrase structure rules (e.g. *this books*)
- transformational rules (e.g. *What reads she?*)

- subcategorisation rules (e.g. intransitive verb (requiring no complements) etc.)
- direct translation (certain idiomatic expressions, e.g. French *avoir faim* 'to have hungry')

Overgeneralisation errors (i.e. errors which are of the above types but are not due to transfer):

- morphological rules (the wrong root and inflection of words)
- phrase structure rules
- transformational rules
- subcategorisation rules

ALICE can detect the following types of error in relation to subordinate conjunctions:

- interference (an Italian student finds it natural to translate the Italian conjunction *come* by the French conjunction *comme*)
- similarity (errors due to the similarity of several conjunctions in a language such as *as long as*, *so long as*, or *as soon as*)
- literal translation (errors that occur in translating compound conjunctions such as a literal translation of the French conjunction *toutes les fois que* will be *all the times that*)
- confusions with adverbs (*afterwards* instead of *after*)
- use of conjunctions omitted in the foreign language (an Italian student is likely to say *Speak louder* **that** *I cannot understand you*)

- use of conjunctions despite syntactic constraints (some conjunctions should be used at the beginning of a sentence e.g. in Italian **Come** *ho sue notizie ti telefono* instead of *Ti telefono* **come** *ho sue notizie*)

XTRA-TE, according to its designers, can detect both syntactic and semantic errors, and thus covers a wide range of errors. The kinds of semantic error detected are: adjective-noun match (e.g. a *considerate* amount of money) and noun-verb match (e.g. *Road walked ten miles*, a word-for-word translation from a Chinese learner).

Schwind's ILTS seems to be able to spot both syntactic and semantic errors. The syntactic errors concern the word order within a sentence (i.e. high level syntactic errors), or additional articles or prepositions (low level syntactic errors). The only type of semantic error detected by Schwind's ILTS concerns the violation of semantic restrictions on verbs and their complements (e.g. in German *Er schreibt dem Heft* (He writes to the notebook)).

eL can pinpoint strong syntax errors and weak syntax errors. The kind of strong syntax error dealt with by eL is misplaced words (e.g. *the man big* instead of *the big man*). The weak syntax errors are incorrect inflection of the present participle *swim* (here *swim* had to be corrected to *swimming*) and the number agreement between the singular determiner 'a' and a plural noun.

The following syntactic errors can be detected by GDC:

- subject-verb discrepancies (*Him will speak to they*)
- the uses of articles
- discrepancies of demonstrative or of the adjectives 'much-many' with singular or plural substantives
- the uses of indefinite pronouns
- defective verbs and infinitives

- the use of verbs 'want' etc. and infinitive verbs

The range of errors detected by the Chinese Tutor will be discussed in *Sections 5.2.*

3. Grammar Diagnosis

Grammar diagnosis refers to the capabilities of a tool in grammatical diagnosis, i.e. whether a tool can automatically detect a wide range of errors using a general set of rules, or has to specify errors which are beyond the capabilities of its parser, or employs a pattern matching mechanism. The automatic detection of errors made by the student indicates a sophisticated grammar diagnoser. The detection of errors using rules for specific errors is a constrained solution, the drawbacks of which have been addressed in *Section 1.1.3.* Some of the existing tools have employed pattern matching mechanisms rather than a parsing strategy. Pattern matching has been used extensively for ITS instruction. Early natural-language processing was done using a template matching approach. It matches the input against a series of predefined templates, binding the variables of the templates to the corresponding pieces of the input stream. This method is less sophisticated than methods based on a grammar for a language and a parser [Slagle 1990].

In most of the existing systems, as can be seen in the following discussion, errors have, to some extent, been predefined.

FGA's grammar diagnosis is constrained, as the designers indicate that expected incorrect structures can be specified and built into the grammar with an appropriate error message tag.

VP^2 can pinpoint errors occurring in the use of two-word verbs, i.e. the use of a wrong verb-preposition combination or incorrect particle by employing a *pattern matching mechanism.*

The grammar diagnosis of Scripsi is sophisticated since it does not need to specify possible errors. Detailed discussions of Scripsi's capabilities and limitations

in detecting transfer errors will be presented in the next section.

ALICE seems capable of dealing with a broad class of students' mistakes in the uses of subordinate conjunctions by *pattern matching.*

The grammatical diagnosis of XTRA-TE is quite sophisticated since, according to its designers, it does not need to prespecify likely errors directly in the grammar. XTRA-TE can detect some of the transfer errors made by native Chinese using subject-verb semantic tests. However, as XTRA-TE's designers have pointed out, XTRA-TE is unable to handle certain transfer errors which are beyond the scope of the grammar: wrong word order is one example of this. We must emphasise here that word order problems involving transfer are extremely hard to pinpoint without modelling the grammar of the student's native language.

The grammatical diagnosis of Schwind's ILTS seems to be quite sophisticated. It is said that Schwind's ILTS can diagnose both low level syntactic errors and one kind of semantic error. However, the designer points out that the high level syntactic errors (i.e. errors concerning transfer at word-order level) have to be specified, so the treatment is not very general.

eL seems to be able to identify both weak syntax errors and strong syntax errors. However, as the designer of eL points out, transfer errors concerning major phrase re-organisation (i.e. word-order transfer) are beyond eL's capabilities.

GDC is able, according to its designers, to deal with syntactic errors mainly in relation to subject-verb discrepancies, the use of articles, indefinite pronouns, verbs and their infinitives. GDC's designers have not mentioned how GDC copes with transfer errors.

How the arbitrary errors made by the student can be automatically pinpointed by the Chinese Tutor is explained in *Sections 5.2 & 6.2.2.*

4. Current State of Learning

This technical feature refers to how a tool/system infers, from the parsing re-

sult, the student's current performance (i.e. whether the student has mastered a particular rule or what types of error have been made). This information will lead to the discovery of the overall performance of the student in connection with a particular kind of task and make it possible for the system to tailor its tutorial strategies accordingly. There are only two existing systems (XTRA-TE and Schwind's ILTS) which can be labelled as 'complete' tutoring systems (i.e. they might possess this feature).

XTRA-TE has some student modelling. Its designers claim that XTRA-TE tries to interpret and understand the student's mastery of the linguistic knowledge according to the information collected on his/her performance. How XTRA-TE undertakes this task, however, is not explained.

The current state of learning of a student is not discussed in Schwind's ILTS.

The mechanism employed by the Chinese Tutor for inferring the current state of the student's learning is explained in *Section 6.2.*

5. Updating of Student Model

In order to find out the overall performance of a student on a particular kind of task, the Student Model needs to be updated after each of the student's answers has been analysed. The Student Model can be updated by changing the values of parameters such as how many times the student has mastered a particular rule, or how often he/she has made a critical error. This information will provide the system with a general view on how the student has performed in the previous tutorial sessions, so the system can make pedagogical decisions tailored to the advantage of the student.

None of the reports on existing tools discusses this important technical feature in student modelling. How the Chinese Tutor updates the learning record of a particular student, will be addressed in *Section 6.2.3.*

6. Tutorial Plans

In order to carry out successful tutorial sessions, a language tutoring system should have tutorial plans: the general guidelines on conditions indicating when the student is allowed to move on to the next lesson; and when additional help should be given to the student.

The only existing tool which addresses this issue is XTRA-TE. XTRA-TE's designers claim that the student will be given harder exercises if he/she is very familiar with the topic of the tutorial; and if the student is totally unfamiliar with the concepts, he/she will be given a tutorial. However, the designers have not explained how XTRA-TE copes with students who have made the same kind of error several times. It seems that XTRA-TE offers the same tutorial strategy regardless of the fact that either the student may have made the same mistake before (i.e. the same tutorial strategy might have been given before and it was not very helpful), or additional help is needed when consistent error has been made.

How the Chinese Tutor plans student learning is explained in *Section 7.2.*

7. Tutorial Strategies

The choice of an appropriate tutorial strategy in intelligent language tutoring is a key factor in ensuring a successful tutorial session. Tutorial strategies are used to offer diagnostics to the student, provide him/her with correct solutions if necessary, give adequate examples to illustrate his/her mistake, and assign appropriate tasks.

The tutorial strategy in ALICE focuses on providing the student with more cloze test type of exercise on a particular conjunction which caused the student's previous error.

The tutorial strategies in XTRA-TE are quite sophisticated. According to its designers, XTRA-TE is equipped with three tutorial strategies: correction (no-hint correction, indirect correction and direct correction), confirmation and coaching. Fuzzy set theory is used in XTRA-TE for evaluating the overall performance of the student, by dividing it up into four levels of familiarity, on which basis the tutorial strategies will be selected. XTRA-TE's pedagogical decisions on which strategies

are selected are more advanced compared with other existing tools. However, XTRA-TE's selection of tutorial strategies cannot be tailored to the benefit of the student, because XTRA-TE does not have a good knowledge of the student's current and general performance on the mastery of a particular kind of grammatical rule.

The coaching strategy of XTRA-TE is different from the coaching strategy in ITSs discussed in *Section 3.1.3*. The coaching in XTRA-TE is used when the student has little knowledge about the concepts (i.e. at level one). The tutor will explain the error, such as subject-verb agreement, and assign appropriate exercises.

Schwind's ILTS's tutorial strategy seems to be quite sophisticated. According to its designer, when errors occur, Schwind's ILTS first indicates that an error exists at a certain place without any explanation. If the student asks why there is an error, he/she is given a hint in the form of a leading question, and if the student still shows misunderstanding, he/she is given the correction and eventually an example. This is a well-designed routine for helping students overcome errors, especially since the examples given to the student will illustrate the usage of a particular rule. However, the tutorial strategies of Schwind's ILTS is not very flexible, as it uses the same strategy each time regardless of what type of error has occurred and cannot select its tutorial strategy on the basis of the current performance of the student (for instance, how serious the error is). Moreover, it cannot tailor its tutorial strategy to the benefit of the student (the same drawback as in XTRA-TE), since it cannot select a different strategy when the student has made the same kind of critical error before.

How the Chinese Tutor selects an appropriate tutorial strategy based both on the current performance of the student and his/her past performance on a particular kind of task will be addressed in *Section 7.4*.

3.2.2 Language Tutoring on Negative Transfer

As has been discussed above, six out of the eight existing tools claim that they can handle errors of mother tongue influence. They are VP^2, ALICE, XTRA-TE, Schwind's ILTS, eL and Scripsi, and we have briefly stated how they cope with errors (including transfer errors) under the technical feature of *grammatical diagnosis.* In this section, we will focus our discussion on the inadequacy of current technology for handling transfer errors.

VP^2 only handles transfer errors in the uses of two-word verbs. Its method of locating transfer errors by pattern matching is not a sophisticated solution for detecting these errors.

ALICE pinpoints transfer errors in the uses of subordinate conjunctions by pattern matching, and this shares the same drawbacks as VP^2.

XTRA-TE can locate some of the transfer errors made by a native speaker of Chinese using subject-verb semantic tests. For instance, if a native speaker of Chinese typed *"Road walked ten miles"*, XTRA-TE could explain to the student that "the action *walk* would require an animate subject". XTRA-TE can detect the above kind of transfer error without having to anticipate them in its grammar. This is a step forward when compared to VP^2 and ALICE. However, XTRA-TE's explanations for transfer errors are not very helpful to the student, because it cannot inform the student that the error mentioned above, is an error of mother tongue influence. Moreover, XTRA-TE is incapable of handling word-order transfer, as has been pointed out by its designers. If the student typed in *I chicken has eaten* (which is not atypical among Chinese students indulging in a word-by-word translation method), XTRA-TE would not be able to detect the misplaced *chicken.* The errors in the sentence could have been handled by a system which had modelled the student's linguistic background.

Schwind's ILTS can, according to its designer, detect transfer errors at the lexical level in the permutation of words. For instance, in German, adjectives precede

the noun (phrase), whereas in French, they frequently follow it. However, the designer points out that errors of transfer at word-order level have to be specified.

The kind of transfer error pinpointed by eL is restricted to misplaced words such as *the man big.* Its designer points out that "most actions can only be taken in the immediate context of the failed word — only local reorganisation is possible (movement of a word)". eL is not very helpful to the student because it explains to him/her the above error as "the word <big> was moved from position <3> to <2>" and cannot report to the student as a transfer error. Moreover, eL cannot detect more complicated transfer errors such as word-order transfer.

Scripsi, compared with the above tools, is by far the most sophisticated tool for treating transfer. According to its designer, it models the linguistic competence of the student (i.e. the grammar of the student's native language) and uses this grammar to locate transfer errors. However, Scripsi has not explained in detail how the grammatical rules of the student's native language (French or Chinese) have been modelled. There are some inadequacies in Scripsi's handling of transfer and these are as follows:

- The grammatical rules modelled by Scripsi are not selected on the results of empirical studies or first-hand materials. Scripsi is not very helpful to the student because it does not model all of the important grammatical rules which cause problems when native French or native Chinese learn English.
- The method employed by Scripsi in modelling the grammatical rules of the student's native language is not very efficient because it models the whole rule in the native language, rather than the fragment of it which is different from that of the target language.
- The range of transfer errors detected by Scripsi is not wide, since its designer does not mention in the paper the detection of combinations of transfer errors. Nor does the designer mention the diagnosis of word-order transfer errors. These two kinds of transfer are very hard to pinpoint because of the complexity of the errors.

- It is not explained how Scripsi copes with transfer errors which only match *part* of a rule at the phrasal or structural level in the grammar of L1.

How the Chinese Tutor detects arbitrary transfer errors including word-order transfers and combinations of transfer errors will be discussed in *Sections 5.2.7 & 6.2.2.* The detection of partial transfer errors will be explained in *Section 5.2.7.*

3.2.3 Summary of the Inadequacies of the Current Technology on Language Tutoring

Name of the Tool	FGA	VP2	Scripsi	ALICE
Year	1986	1986	1988	1989
Empirical Studies	no	no	no	no
Learning Environment	free-formed	translation	free-formed	a close test
Correctness of Input	well-formed ill-formed	well-formed ill-formed	well-formed ill-formed	well-formed ill-formed
Grammatical Coverage	unspecified	limited	unspecified	limited
Range of Errors Diagnosed	syntactic	transfer in verb sub-categorisation	transfer & overgenera-lisation	transfer in subordinate conjunctions
Grammatical Diagnosis	restricted	restricted	sophisticated	restricted
Ambiguous Cases	unspecified	unspecified	unspecified	unspecified
Student's Linguistic Background	no	a limited aspect	yes	no
Current State of Learning	no	no	no	no
Updating Student Model	no	no	no	no
Tutorial Plans	no	no	no	no
Tutorial Strategies	no	no	no	some
Testing on Students	no	no	no	no

Table 3.2: The Existing Language Tools I

Tables 3.2 & 3.3 show that, in the field of intelligent language tutoring, there is no existing system which has been designed according to the instructional needs of the field of language learning and is equipped with all of the important technical features for the development of an ILTS.

Name of the Tool	XTRA-TE	Schwind's ILTS	eL	GDC
Year	1989	1990	1992	1993
Empirical Studies	no	no	no	no
Learning Environment	free-formed translation	free-formed translation	free-formed	free-formed
Correctness of Input	well-formed ill-formed	well-formed ill-formed	well-formed ill-formed	well-formed ill-formed
Grammatical Coverage	large	unspecified	unspecified	medium
Range of Errors Diagnosed	syntactic & some semantic	syntactic & some semantic	syntactic	syntactic
Grammatical Diagnosis	quite sophisticated	quite sophisticated	restricted	restricted
Ambiguous Cases	unspecified	unspecified	unspecified	unspecified
Student's Linguistic Background	no	no	no	no
Current State of Learning	some	unspecified	no	no
Updating Student Model	no	no	no	no
Tutorial Plans	some	unspecified	no	no
Tutorial Strategies	quite sophisticated	quite sophisticated	no	no
Testing by students	yes	no	no	no

Table 3.3: The Existing Language Tools II

Chapter 4

Outline of the Solution

Having examined the capabilities and limitations of current technology in intelligent language tutoring and in handling negative transfer, we can embark on providing a design for a system which can deal with not only the aspects that other systems can handle, but also aspects that they cannot. As has been discussed in *Section 3.2*, in the field of intelligent language tutoring, there is a need for a language tool, the design of which is based on empirical/scientific data and which can provide successful tutorial sessions for tackling real problems in the field of language learning.

The goal of our research is to discover what are the difficulties encountered by first-year students at Durham University when they learn Chinese grammar and propose a general solution to help students to overcome these difficulties. In order to obtain first-hand materials on these difficulties, we have undertaken empirical studies (as described in *Chapter 2*) by monitoring the progress of the students as they learn Chinese grammar. The empirical studies focused on discovering common errors made by students and included the classification of the types of error made and their frequency.

According to the results of the empirical studies, errors of mother tongue influence can be used to account for most of the errors which students make. If the

students could overcome these errors, it would lead to an improvement in their standard of Chinese grammar.

How can students be helped to correct these errors more usefully than if they simply did exercises on their own? We believe an effective way of tackling the problem of transfer is using an intelligent language tutoring approach. This is because an intelligent language tutoring tool can provide students with immediate feedback and tailor its tutorials to the needs of the students.

A central concern in the design of an intelligent language tutoring tool is the automatic detection of errors made by the students. A general solution to the problem of transfer is needed because the handling of transfer errors by the existing tools is not robust, since most of them use constrained solutions by specifying these errors. Even tools which do not need to specify errors could not cope with complicated transfer errors (e.g. word-order transfer, combinations of transfer, and transfer errors in incomplete sentences, which can be called 'partial' transfer).

How can the tool provide successful tutorial sessions for the students? It should overcome the limitations of the existing tools by having both pedagogical value (i.e. the design of such a system should be based on empirical data), and the important technical features that we have discussed in *Section 3.2.*

In this chapter, the advantages of the intelligent language tutoring approach will be addressed, followed by discussions on why the Mixed Grammar approach is employed and why a natural language parser is used. We will then move on to the overall organisation of the Chinese Tutor.

4.1 Computer-based Tutoring Approach

Very little research has been done in helping students to remove negative transfer in the field of language learning and intelligent language tutoring. The only method that we found in the literature on tackling negative transfer in the field of language

learning is to encourage teachers to focus their teaching on the areas of difficulty created by negative transfer, and to apply massive practice to overcome these difficulties [Ellis 1991c]. However, the scope of this research does not lie in the field of language teaching, i.e. how teachers should teach Chinese, but how English-speaking students can be helped by a language tool to overcome transfer errors in their first-year study of Chinese grammar.

We believe that an effective way of helping students overcome errors of transfer is through an intelligent tutoring approach. The following is a list of advantages of using an ILTS.

- ILTSs can help students solve practical problems such as negative transfer by providing them with a sufficient number of well-designed tasks which will eventually lead to mastery of the topics introduced.
- This kind of system can give students immediate responses, commenting on their performance, offering guidance and selecting the next task for them to do. This is very different from letting students do exercises themselves, because they do not need to wait and ask their teachers for explanations when they encounter difficulties.
- These systems could provide highly individualised instruction, with the shape of the lesson adapting automatically to the ability demonstrated by the students.
- These systems can provide student-centred instruction which allows them to work on their own, in their own time and, most importantly, at their own pace.
- The slower learners, who need a great deal of help (which they sometimes fail to obtain through classroom teaching), will be given more time and attention by these systems.
- The systems can assign more difficult tasks to the better students, who learn faster.

- By interacting with these systems, the students can test their own hypotheses without the fear of being embarrassed when they make mistakes.

4.2 Technique of Mixed Grammar

As has been discussed in *Section 3.2*, most of the existing tools provide constrained solutions to the treatment of transfer errors. The only tool which handles transfer in a sophisticated manner is Scripsi, which models the grammars of the students' native language. However, there are two main drawbacks in Scripsi's approach. The first drawback is that Scripsi duplicates, in the grammar, linguistic knowledge of the students' native language in the sense that it models this grammar regardless of the fact that some of the rules in this grammar could be the same as those in the grammar of the target language. The second main drawback is its simplistic error detection routine, i.e. only looking at the error itself. A much more sophisticated tool should look not only at the error, but also at its link(s) with the other constructs of the sentence in order to detect complicated transfer errors.

To overcome the current inadequacies in handling transfer errors, we propose a general and robust solution, the technique of Mixed Grammar, i.e. of Chinese and English. The Mixed Grammar of Chinese and English models approximately 250 grammatical rules of Chinese and English which lie behind students' transfer errors identified in the test papers. The English rules in the Mixed Grammar are used to detect arbitrary transfer errors made by the student, while the Chinese rules are applied to handle non-transfer errors.

The method which has been used by this research, for modelling the rules of the native language (English), is more efficient than that of Scripsi, because the Mixed Grammar does not duplicate those of the grammatical rules of the students' native language which are the same as that of the target language. For instance, in the test papers, quite a few students have translated the English sentence "*Her English friend works in the library*" into a Chinese sentence that conforms to the English

structure. The correct Chinese translation should be in the order *her English friend in library work.* At the beginning of the two structures, i.e. at the noun phrase level, the English is identical to the Chinese. Therefore, this noun phrase will not be modelled in the English rules in the Mixed Grammar, while the rest of the rule (the prepositional verb phrase) will.

The Mixed Grammar can be used to pinpoint a wide range of transfer errors, both simple and complicated, by allowing its parser to switch from Chinese rules to English ones or vice versa as many times as necessary in analysing a single input.

The parser used in analysing the input can, by checking the rules in the Mixed Grammar, provide a parsing result with the fired English rule(s) clearly marked. The marking of the transfer error where the English rules were necessary in the parse tree makes it possible for the Diagnoser to infer the type of transfer error made by the student. It also makes it possible for the Tutor Model to help the student effectively remove the error by delivering appropriate explanations, examples and standard translations.

The technique of Mixed Grammar will be explained in depth in *Section 5.2* and some examples of Mixed Grammar are shown in *Appendix C.*

4.3 Use of a Natural Language Parser

An important issue in natural language processing is to build a natural language parser. This is usually a very complicated task. The parser used in the Chinese Tutor is the natural language parser from the LOLITA system (Large-scale, Object-based, Linguistic Interactor, Translator and Analyser) [Garigliano 1992] which has been developed at the University of Durham over the last 8 years. Although the system was initially developed by Dr. Garigliano, a team of approximately 20 people are currently engaged in developing various aspects of LOLITA.

The LOLITA system consists of approximately 35,000 lines of source code in

Miranda, and divided between 250 modules. A detailed explanation of how the parser undertakes its parsing tasks is given in *Section 5.2.5.* The following are the reasons for using the syntactic parser of LOLITA:

- Using LOLITA's parser rather than building our own parser from scratch, saves a great deal of time.
- The parser of LOLITA has been shown to work in a considerable number of cases over the last 8 years. The major bugs have been eradicated.
- The parser is sufficiently fast because the top-down parsing strategy has been improved by incorporating initial bottom-up parsing to cut down the search space.
- The parser is easy to understand since it has been implemented using abstract types [see *Glossary*] in Miranda. The advantages of using abstract types will be discussed in *Section 9.1.3.*
- The Mixed Grammar is very easily integrated into the LOLITA system. It requires only one new function to be added to the LOLITA parser to cope with switching from the Chinese grammar to the English one, when no successful parse is found using the Chinese grammar, and vice versa. These functions can be seen in *Section 5.2.4.*
- The Chinese dictionary can easily be implemented according to the defined framework in LOLITA, apart from some special Chinese features which need to be added.

4.4 Overall Organisation of the Chinese Tutor

The Chinese Tutor contains five main components: the Expert Model, the Student Model, the Diagnoser, the Tutor Model and the Interface Module. These models are indispensable elements for carrying out a successful tutorial session. The design

of the Chinese Tutor has been based on empirical data that we have collected, expertise [See *Appendix B*] on Chinese grammar and personal teaching experience of Chinese.

In this section, the basis for the design of the Chinese Tutor is addressed, followed by the overall structure of the Chinese Tutor and its basic operation.

4.4.1 Basis for the Design of the Chinese Tutor

The design of the domain knowledge of the Chinese Tutor's Expert Model has been based on the results of the data analysis. In order to help students to overcome the difficulties in their study of Chinese grammar, a sufficient number of translation exercises, additional exercises, examples and explanations have also been designed in the domain knowledge.

The general teaching knowledge and tutorial plans have been designed on the basis of the experts' knowledge [see *Appendix B*] and personal teaching experience of Chinese. We have elicited knowledge from experts on the Chinese language. This knowledge has provided us with guidelines for the design of the tutorial strategies in the Tutor Model [see *Section 7.1*].

The techniques that have been used for knowledge acquisition include both formal and informal approaches. The formal approach for acquiring knowledge involved issuing a questionnaire for the experts to complete [see *Appendix A*]. The questionnaire has been distributed to the Oriental Faculty at Cambridge, the Oriental Institute at Oxford, the Department of East Asian Studies at the University of Leeds, and the Department of East Asian Studies at the University of Durham. The informal approach involved interviewing experts on Chinese from China Renmin University in Beijing and from the Department of East Asian Studies at the University of Durham. The knowledge acquisition, both formal and informal, focused on the tutorial techniques that these experts employ in helping their students overcome common errors when they study Chinese.

4.4.2 Overall Structure of the Chinese Tutor

The main components of the Chinese Tutor are the Expert Model, the Student Model, the Diagnoser, the Tutor Model and the Interface Module. The Chinese Tutor also includes a help system [see *Figure 4.1*].

The Expert Model

The object of learning is knowledge or expertise in some domain. The Expert Model of the Chinese Tutor embraces the domain knowledge which represents the subject for tutorials and provides the system with expertise.

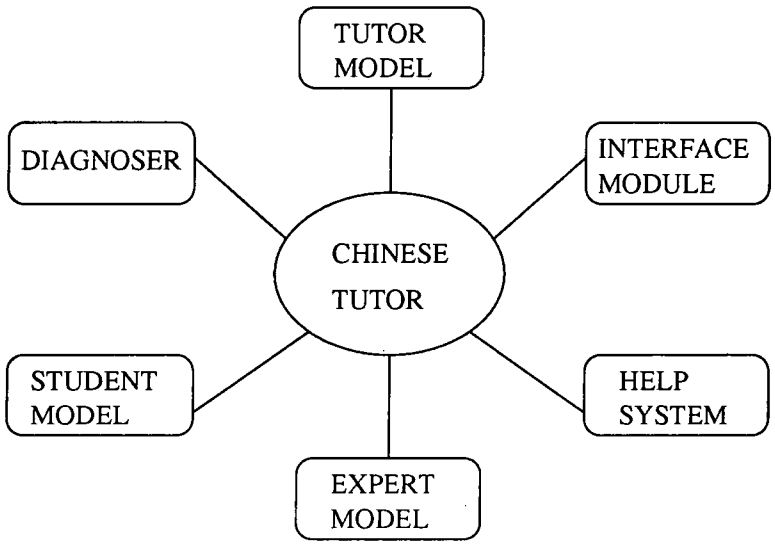

Figure 4.1: Main Components of the Chinese Tutor

The Student Model

In order to carry out a tutorial session successfully, a certain understanding of the student is needed. The Student Model of the Chinese Tutor collects information about the student's current state of learning and keeps a record of his/her learning history. The Student Model also updates the student's learning record after each of the student's answers has been analysed.

The Diagnoser

Accurate detection of the type of error which has occurred, is of great importance within language tutoring. The Diagnoser of the Chinese Tutor can correctly detect both transfer errors and non-transfer errors. It can also calculate to what extent the English sentence has been translated correctly.

The Tutor Model

The idea of how to communicate knowledge is another important ingredient in language tutoring and is represented as a tutor model. The Tutor Model of the Chinese Tutor selects an appropriate tutorial strategy based on the diagnostic result and the updated Student Model. It also plans student learning and makes didactic decisions by referring to the results of the Student Model and the Diagnoser.

The Interface Module

There is also a need for communication between the student and the system. The Interface Module of the Chinese Tutor takes care of the final output of the system and interacts between the system and the student.

4.4.3 Basic Operation of the Chinese Tutor

The Chinese Tutor operates in the following ways [see *Data Flow Diagram 4.2*]:

- the Interface Module starts the tutorial by getting the *name* of the student and gives it to the Student Model in order to keep a record of the student's learning history.
- it then provides the student with a lesson selection menu and asks him/her to choose a lesson for the tutorial;

- it informs the Tutor Model of the *lesson number* that has been specified;
- the Tutor Model selects a *translation exercise* for the student from that lesson, passes it to the Student Model for inclusion and outputs it to the student through the Interface Module to be answered;
- the Interface Module collects the answer, i.e. the *student's input* from the student and passes it on to the Student Model as a record of his/her learning history;
- the Student Model hands over the *student's input* to the parser in the Expert Model for evaluation;
- after the parser generates a *parsing result*, it gives this result back to the Student Model for keeping the learning record;
- the Student Model then gives the *parsing result* to the Diagnoser for further examination;
- the Student Model updates the learning record based on the diagnostic result, i.e. *diagnosis*;
- the Tutor Model selects an appropriate *normal tutorial strategy*, after the Diagnoser has finished its tasks and the Student Model has been updated;
- if an additional tutorial is needed, the Tutor Model will output a series of additional exercises (i.e. *next task*) through the Interface Module to the student;
- the Interface Module collects the student's *input for the additional exercise* and hands over to the Tutor Model for evaluation;

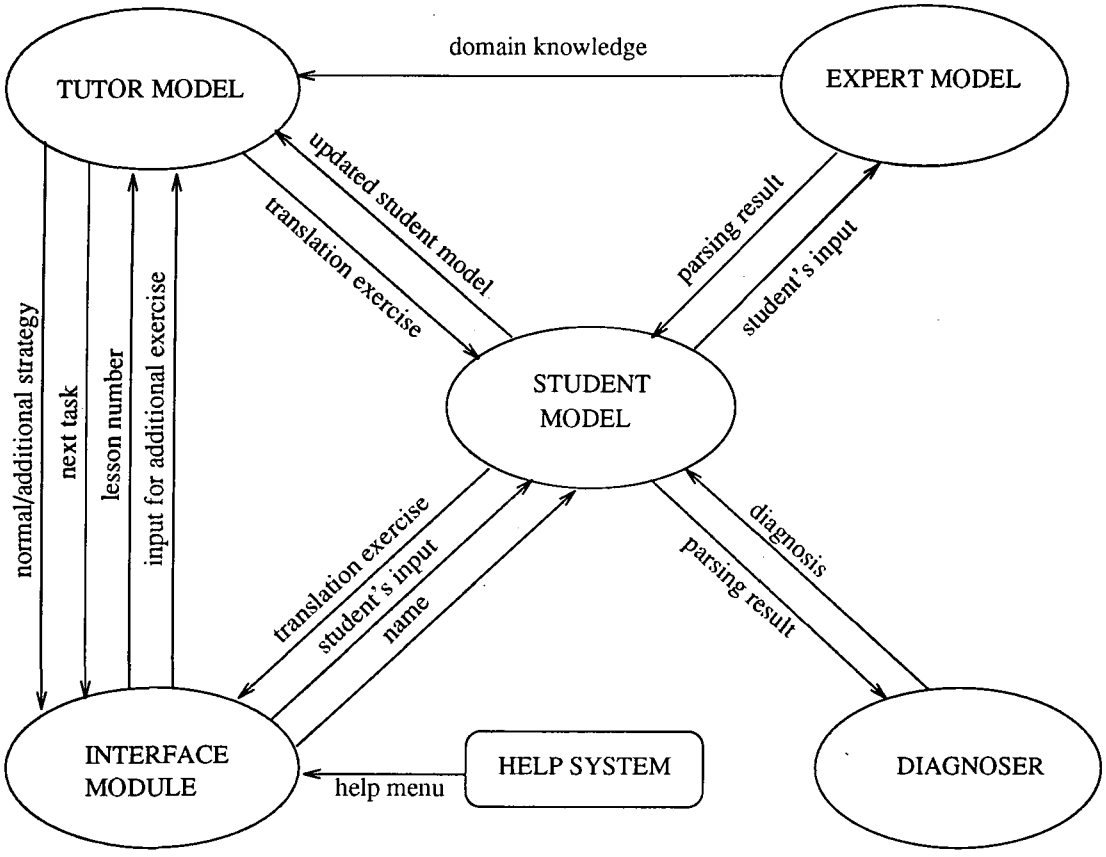

Figure 4.2: The Language Learning Environment Provided by the Chinese Tutor

- the Tutor Model selects the *next task* for the student to do;
- the Expert Model provides *domain knowledge* to the Tutor Model;
- the help system can be accessed at any level in the Chinese Tutor when the student is asked to enter a choice of topic or an answer.

Chapter 5

The Expert Model

In conventional Computer-Aided Instruction, as has been discussed in *Section 3.1.1*, the expertise to be conveyed is held in prestored presentation blocks, sometimes called *frames*, which are designed by an expert teacher and are simply displayed to the student when certain conditions arise. In ITSs, there is a special model, often called the *expert*, that contains a representation of the knowledge to be communicated. In most cases, this representation of the subject matter not only describes the various concepts and skills that the student is to acquire, but also provides the system with a *dynamic* form of expertise [Wenger 1987a].

The Expert Model of the Chinese Tutor fulfills two tasks. On the one hand, it acts as the source of the knowledge to be presented. This knowledge is used for extracting tasks, standard translations, examples and explanations. On the other hand, the Expert Model functions as a standard for evaluating the student's performance and this is undertaken using a parser.

In order to facilitate students in overcoming mother tongue influence in their first-year study of Chinese grammar, the Chinese Tutor should model all the linguistic knowledge needed to help them grasp those grammatical rules which, as indicated by our empirical data, have caused many problems. The domain knowledge of the Expert Model should contain the following kind of linguistic knowledge:

- a **dictionary** which contains all of the vocabulary students will learn in their first-year of studying Chinese grammar;
- a **grammar** with all of the important Chinese rules in the two textbooks used by first-year students;
- the fragments of **English rules** which are behind the students' errors of transfer should also be modelled in the above grammar;
- a reasonable number of well-designed **translation exercises**, which are similar to the translation exercises set up by the human teachers in the test papers, but concentrate more on practising those rules which students failed to grasp;
- all the possible **standard translations** for the translation exercises;
- **additional exercises** for helping those students whose learning of Chinese grammar has been greatly influenced by their mother tongue;
- **answers** for additional exercises;
- **examples** and **explanations**.

Apart from the linguistic knowledge mentioned above, the domain knowledge should also contain a parsing strategy. The parser of the Chinese Tutor should act as a standard for judging the performance of the student.

For the convenience of this discussion, the domain knowledge of the Chinese Tutor has been divided into two parts. In Part One, issues in connection with the linguistic knowledge of Chinese (apart from the Mixed Grammar) will be addressed. In Part Two, we will focus on the Mixed Grammar of Chinese and English and the parsing strategy of the Chinese Tutor.

5.1 Domain Knowledge I

In this section, the following design issues will be addressed: the Chinese Dictionary; the translation exercises and the standard translations; the additional exercises and their standards; and examples and explanations.

5.1.1 The Chinese Dictionary

The Chinese dictionary contains approximately 1,000 Chinese words and covers all of the vocabulary in the books Modern Chinese Beginner's Course I and II. These books are used as textbooks for first-year students in the Department of East Asian Studies at Durham. The words have been stored with their syntactic categories. The syntactic categories are equivalent to parts of speech in conventional grammar but have a finer grouping, so the system can work more efficiently. The following are some examples of how the information in connection with a word is stored in the dictionary:

他

inrep: 19154

category: human

type: pronoun

pronoun type: personal

For the word 他 , which means "he" in English, the dictionary contains the following information: an internal representation number (for reasons of efficiency), the category (human), the type (pronoun) and the type of pronoun (personal).

0 把

inrep: 19263

type: preposition

preposition type: object marker

1 把

inrep: 28767

type: measure word

measure word type: nominal

Words with more than one part of speech such as 把 (which has no English equivalent), are stored in an index format. The first 把, marked with number 0, belongs to the type preposition and is an object marker. The second 把 belongs to the type measure word and is a nominal measure word.

5.1.2 Translation Exercises and Standard Translations

The translation exercises have been designed to help students grasp the grammatical rules which cause a considerable number of problems among first-year students in their study of Chinese. There are approximately 2000 translation exercises and standard translations in the Chinese Tutor. The Chinese Tutor can offer students translation exercises on 17 lessons which cover 24 important grammatical points addressed in the two textbooks. Some examples of translation exercises and standard translations are shown in *Appendix I* and *Appendix J* respectively.

For each translation exercise, all of the possible standard translations have been formulated. Some exercises will have only one possible translation, while others may have many translations. The standard translations have been stored and formulated using the knowledge that students should have gained from the two textbooks. The standard translations provided by the Chinese Tutor are not translations generated by machine (which is what translation systems attempt to do), as this research is not in the field of machine translation. The reason that we can afford to do this by hand is that there are normally only a few ways of translating a particular sentence in the exercises. This is because at a certain stage in the student's learning process, the student's grasp of Chinese grammatical rules

and vocabulary is rather limited. This has helped us to narrow down the choices of other possible translations.

The following is a list of the lessons for tutorials provided by the Chinese Tutor, with a brief explanation of each of the grammatical points given at the end of the list. The letters after the lesson numbers such as "14a" are used to indicate that there is more than one grammatical point in that lesson.

Lesson 6	interrogative with the link verb 是 (*be* in English)
Lesson 8	interrogative with verbs such as 买 etc.
Lesson 10	interrogative with the coverb 在 (*be at* or *in a certain place*)
Lesson 13	use of the coverb 在 as a verb
Lesson 14a	prepositional phrases formed with the coverb 在 as adverbials of place in affirmative sentences
Lesson 14b	prepositional phrases as adverbials of place in questions
Lesson 16	time words as adverbials of time in affirmative sentences
Lesson 17a	time words as adverbials of time in questions
Lesson 17b	use of the point of time
Lesson 21	how to ask age, height and weight
Lesson 24	use of the verb 完 (*finish*) indicating the result of actions
Lesson 25a	polysyllabic adjectives as predicates
Lesson 25b	monosyllabic adjectives as predicates
Lesson 25c	use of negations in adjectives

Lesson 28a	prepositional phrases formed with the preposition 跟 (*with*) as adverbials I
Lesson 28b	use of prepositions such as 离 (*away from*)
Lesson 30a	use of serial verbs such as 坐 (*sit*)
Lesson 30b	use of numbers and measure words
Lesson 34	prepositional phrases formed with the preposition 跟 as adverbials II
Lesson 37	use of serial verbs such as 让 (*let* or *ask*)
Lesson 40a	use of serial verbs such as 用 (*use*)
Lesson 40b	verbs, verb phrases and subject-predicate phrases as attributives
Lesson 44	把 construction
Lesson 54	被 construction (*passive voice*)

Lessons 6 and **8** concentrate on how interrogative questions in Chinese should be formed. The structure of interrogative questions in Chinese is very similar to that of Chinese affirmative sentences, which is different from the structure of interrogative questions in English. According to the empirical data, the difference between the structure of interrogative questions in Chinese and English has caused students' problems. The structure of an interrogative question with the link verb 是 in Chinese can be formed thus:

pronoun + link verb + interrogative pronoun

he is who

while the English equivalent will be:

interrogative pronoun + link verb + pronoun

who is he

Lessons 10 and **13** deal with the use of the coverb 在 (*to be in/at*)Quite a few students made some errors which seem to be caused by referring to the link verb in English. For instance, some students translated the link verb in the following English sentence: *Where* **are** *you?* into Chinese literally, which led to a transfer error. The coverb should be used in this type of sentence.

Lessons 14a and **14b** handle the use of adverbials of place formed with the coverb 在 . This is an important grammatical structure in Chinese which caused a great number of problems among students. In Chinese, this type of adverbial or prepositional phrase normally precedes the verb/predicate; while in English it normally follows the verb/predicate.

Lessons 16, **17a** and **17b** focus on the use of adverbials of time, a very important grammatical point in Chinese. Time words or time phrases in Chinese normally either precede verbs/predicates or appear at the beginning of a sentence. They cannot, however, be put at the end of a sentence, as they can in English.

Lesson 21 is about how to ask age, height and weight in Chinese. For instance, the structure of the English sentence *How big is China?* is different from the equivalent Chinese structure which is:

中 国 *(China)* 多 *(how)* 大 *(big).*

Lesson 24 is the use of the verb 完 which can follow other verbs and act as a complement to indicate the result of the action described by the first verb. For instance: the phrase *finish watching TV* in English can be translated as:

看 (*watch*, the first verb) + 完 (*finish*, the complement) + 电 视 (*TV*, the object)

in Chinese.

Lessons 25a, **25b** and **25c** focus on another important grammatical point, the use of adjectives, which caused a considerable number of errors among students. In Chinese, a lot of adjectives can be used as verbs alone, which means that they are

independent of link verbs. This is different from the equivalent English structure in which a link verb must be used.

Lessons 28a, 28b and **34** deal with the use of adverbials formed with prepositions 跟 and 离. The structure of this type of sentence is more or less the same as that of **Lesson 14a.**

Lesson 30a tackles the use of the serial verb 坐 . For instance, the phrase *go to school by bus* in English can be translated as

坐 (*sit*, the serial verb) 汽 车 (*bus*) 去 (*go*) 学 校 (*school*)

in Chinese.

Lesson 30b focuses on the use of numbers and measure words. For instance, in Chinese, a measure word normally follows a number 一 号 (*1 Number*), instead of *Number 1* in English.

Lesson 37 concentrates on the use of the verb 让, which caused quite a few problems. The reason behind the errors is that the English word "ask" can be translated into two different Chinese verbs, 让 or 问, depending on the context of a particular sentence. The former should be applied in a sentence indicating *ask somebody to do something*; while the latter is used when *asking a question* is indicated.

Lesson 40a is the use of the serial verb 用 which is similar to that of **Lesson 30a.**

Lesson 40b is another key grammatical point in Chinese, verbs, verb phrases and subject-predicate phrases used as attributives, which is similar to the relative clause in English. However, the structures of the two are quite different.

Chinese: verb phrase + 的 (particle) + modified noun

wear glasses of man

English: modified noun + relative pronoun + verb phrase

the man who wears glasses

Lesson 44 is one of the most important and difficult grammatical points in Chinese grammar, the 把 construction, which caused a great number of errors among students. A sentence with a verb predicate modified by the preposition 把 and its object is called the 把 construction. This construction indicates that an action is applied to somebody or something that the action will bring about a result or influence. The students' errors may have been caused by the absence of this construction when it was obligatory. In Chinese, this construction must be used, when the coverb 在,taking an object of locality,,acts as the complement of the result for the predicate, showing where the person or thing is as the result of the action. The following shows the difference between the structure of a Chinese 把 sentence and the equivalent English one.

proper noun + preposition + noun (receiver) + verb + other elements

Tom 把 his clothes put in cupboard

proper noun + verb + noun (receiver) + other elements

Tom put his clothes in the cupboard

Lesson 54 is the 被 construction, which is similar to the passive voice in English. A sentence with a verb predicate modified by a passive preposition and/or its object is called the 被 construction.This construction indicates that a person or thing (the subject) is subject to a certain result influenced by the action of the verb. It often describes an action that the subject is not willing to accept or an action from which the subject will suffer. The basic pattern of this construction is:

Receiver of the action + the preposition 被 + doer of the action + verb + other elements

This is different from the basic structure of the passive voice in English:

Receiver of the action + verb in passive voice + by + doer of the action

5.1.3 Additional Exercises and Their Standards

The additional exercises have been designed to help those students whose learning of Chinese grammar has been greatly affected by English sentence structure. The Chinese Tutor helps the students by providing them with some simple exercises which are formed not only using the basic structure of a particular rule, but also simple vocabulary, thus making it possible for the students to concentrate on the formation of a particular grammatical rule. This is different from doing translation exercises because the students do not need to worry about how a Chinese sentence should be produced and which vocabulary should be used.

There are two kinds of additional exercise: pair choice exercise and sentences built up from constituents. Pair choice exercises are used to check if the student can distinguish the correct sentences from incorrect ones. Sentences built up from constituents are used to check if the student can form a correct Chinese sentence. Some examples of pair choice exercises and sentences built up from constituents are given in *Appendix K* and *Appendix L* respectively.

5.1.4 Examples and Explanations

Examples are used to help students achieve a better understanding of certain grammatical rules which they may find difficult. Explanations are provided to inform the student where their translation has gone wrong, and how a correct translation can be constructed.

5.2 Domain Knowledge II: The Mixed Grammar of Chinese and English

The technique of Mixed Grammar has been specially designed for tackling the problem of transfer. In this section, the following issues in relation to the technique

of Mixed Grammar of Chinese and English will be addressed:

- the importance of modelling the grammar of students' native language;
- the selection of the grammatical rules in the Mixed Grammar;
- the modelling of these rules;
- the Mixed Grammar formalism;
- how the parser works;
- examples of how the parser works;
- the automatic detection of transfer errors;
- the detection of transfer errors decides the success of the tutorial;
- possible transfer errors;
- and examples of parsing results.

5.2.1 Importance of Modelling the Grammar of Students' Native Language

The grammar of the students' native language can be used to analyse students' errors of transfer and thus submit transfer to critical observation. There are two reasons for modelling the grammar of the students' native language.

- According to the results of the analysed data, the grammar of the students' native language can be used to explain 78% of the errors made by the students in their study of Chinese [see *Section 2.2.4*]. The rules of the native language which lie behind students' transfer errors should be modelled as they can be applied to detect mother tongue influence.

- As has been discussed in *Section 3.2.2*, most of the existing tools need, to some extent, to specify transfer errors. In order to fulfill the task of parsing without specifying this kind of error, the grammatical rules of the students' native language need to be modelled.

5.2.2 Selection of the Grammatical Rules in the Mixed Grammar

On the basis of the data that has been collected, we decide which kinds of grammatical rule needed to be included in the Mixed Grammar. The following is the procedure for choosing these rules: *firstly*, we analyse the students' Chinese translations from the students' test papers and identify the common errors (i.e. transfer); *secondly*, we extract the grammatical rules, of both Chinese and English, behind the examples; and *finally* we model these rules.

The Mixed Grammar of Chinese and English contains approximately 250 rules, and compared with other existing tools it is of *reasonable* size. All of the important grammatical rules behind students' transfer errors in the test papers have been modelled in this grammar. These grammatical rules cover most of the grammar points in the first two volumes of Modern Chinese Beginner's Course, on which the first-year grammar teaching is based.

5.2.3 Modelling of These Rules

The Mixed Grammar of Chinese and English consists of Chinese rules and fragments of English rules which show the differences or similarities between the two grammars. The Chinese rules are complete for the features that needed to be

covered, the English rules are fragments which occur only when they are appropriate. The Mixed Grammar of Chinese and English is used for parsing the Chinese sentences input by the students. The advantages of the technique of the Mixed Grammar has been discussed in *Section 4.2.*

5.2.4 The Mixed Grammar Formalism

In *Section 4.3* (*Use of a Natural Language Parser*), it was stated that only one new function (an inclusive or) need be added to the Lolita parser in order to locate errors which could be explained using the grammatical rules of the students' native language.

The Mixed Grammar is written as a collection of function definitions which look very similar to the declarative rules of a phrase structure grammar [see *Glossary*]. The basic approach described in [Frost 1989] has been extended in the Lolita system to deal with large grammars efficiently and also to deal with mixed grammars. So that the following description is understandable to readers who have little experience with functional programming languages, we present the Mixed Grammar using the standard notations for phrase structure grammars, augmented with a special notation for the Mixed Grammar rules. This special notation allows a rule to be modelled as an error rule by placing the symbol "(error)" at the end of the line on which the rule occurs.

The following is an example of a small Mixed Grammar with rules numbered for convenience:

1	S	->	NP	VP
2	NP	->	N	
3	NP	->	PRON	
4	NP	->	ADJ	N
5	NP	->	LNP	
6	NP	->	MP	
7	NP	->	DNP	
8	LNP	->	N	LN
9	MP	->	DNM	NP
10	DNM	->	DNO	MW
11	DNO	->	DP	
12	DNO	->	NUM	
13	DNP	->	DNO	NP (error)
14	VP	->	OMP	DCP
15	VP	->	DVP	
16	OMP	->	OM	NP
17	DCP	->	DV	CCP
18	CCP	->	(C)	LNP
19	DVP	->	DVS	CECP (error)
20	DVS	->	DV	NP
21	CECP	->	CCP	
22	CECP	->	ECP	
23	ECP	->	C	NP (error)

Definitions:

NP	=	noun phrase
VP	=	verb phrase
N	=	noun
PRON	=	pronoun
ADJ	=	adjective
LNP	=	noun phrase of locality
MP	=	measure word phrase
(error)	=	the error construct
DNP	=	demonstrative pronoun & numeral phrase
LN	=	locality noun
DNM	=	demonstrative pronoun or numeral, with a measure word
DNO	=	demonstrative pronoun or numeral
MW	=	measure word
DP	=	demonstrative pronoun
NUM	=	numeral
OMP	=	object marker phrase
DCP	=	disposal verb & coverb phrase
DVP	=	disposal verb phrase

```
OM      =   object marker
DV      =   disposal verb
CCP      =  Chinese coverb phrase
C       =   coverb
DVS     =   disposal verb structure
CECP    =   Chinese or English coverb phrase
ECP     =   English coverb phrase
```

Rules with the symbol "(error)" at the end of the line in above examples represent English rules, and rules without such a symbol represent a Chinese rule. The first rule states that a sentence consists of a noun phrase and a verb phrase. Rules 2–13 are noun phrase rules. The "(error)" symbol marked at the end of Rule 13 indicates an English rule. Rules 14–23 are verb phrase rules, with Rules 19 and 23 marked as English rules. The round brackets in Rule 18 indicates optional. The 15 rules given above can be used for analysing either correct Chinese sentences with the 把 construction, or incorrect ones which could be parsed using the grammatical rules of the student's native language.

The examples above should be self-explanatory, apart from the error construct. This is used to indicate possible transfer errors. The parser tries to find a parse which involves the minimum number of error rules. The semantics of the error construct can therefore be described as follows. The input sentence is parsed using only the rules which are not error rules. If the student's input is parsed successfully, this indicates that it is a syntactically correct Chinese sentence. If however, the input is not parsed successfully, it is then parsed with each of the grammars obtained by removing all but one error rule from the original grammar. If this is successful, a single transfer error can be diagnosed. If this in turn is not successful, the input is parsed again with two error constructs retained. If this succeeds, a combination of transfer errors can be diagnosed. The input is considered not parsable if no parse is found with all of the error rules applied.

5.2.5 How Does the Parser Work?

The parser, which is located in the Expert Model, is able to detect arbitrary transfer errors automatically from the student's input. It can detect either a single error or a combination of errors (i.e. a combination of transfer errors, a combination of non-transfer errors, and a combination of transfer and non-transfer errors) [see *Section 6.2.2*]. The parser which uses the natural language parser of the LOLITA system, can parse both simple and complicated Chinese sentences. The Chinese rules in the Mixed Grammar are used mainly to diagnose lexical and syntactic errors, while the English rules are applied to handle errors of transfer.

The student's input is checked for correctness against the Mixed Grammar through the analysis of the parser. The parser works in a top-down [see *Glossary*], left-to-right and depth-first mode. However, this strategy has been further improved using an initial bottom-up parse [see *Glossary*] to avoid blind search.

The parser begins by operating bottom-up, until it has identified the categories of all of the lexical items in the input from the Chinese dictionary. The parser goes through each word in the input and checks it against the Chinese dictionary to see whether they are actual Chinese words. If the student uses a word that does not exist in the Chinese dictionary, it will be dealt with as an unknown word. The unknown word will be handled by allocating it to any category that suits its position, making a note of it and reporting to the student later that the word does not exist.

After the parser has identified all the categories of the lexical items in the input, it starts checking the categories against the Chinese rules in the Mixed Grammar, operating top-down in its search for the high-level syntactic structure. Whenever the parse meets an alternative with an error in it, the parser will not immediately follow this rule but mark it as a site for possible backtracking later.

When the parser fails to parse the input using Chinese rules, it starts incorporating English rules by backtracking to the last marker that was left, and applies

the English rule at that point. If that fails, the parser will backtrack to the marker before that. This procedure can be repeated as often as is necessary until no further backtracking point is available.

5.2.6 Examples of How the Parser Works

In this section, we will demonstrate how the parser applies the Chinese and English grammatical rules to a couple of Chinese sentences.

Example 1 demonstrates how the parser analyses a correct Chinese sentence, applying only the Chinese rules. Example 2 will show how the parser switches from the Chinese to English rules and vice versa, in order to detect complicated errors which could be interpreted as transfer errors. Both of these examples relate to the simple grammar rules given in *Section 5.2.4*.

Example 1:

Chinese: 他 (he) 把 (no English equivalent) 那 (that) 台 (no English equivalent) 新 (new) 电 视 (television) 放 (put) 在 (on) 桌 子 (table) 上 (top).

English: He puts the new television on the table.

Once the student has entered the above Chinese sentence, the parser first determines the grammatical category of each word of the input by looking it up in the Chinese dictionary (initial bottom-up parsing). The result of bottom-up parsing for this particular sentence looks like the following:

[(他 , PRON), (把 , OM), (那 , DP), (台 , MW), (新 , ADJ), (电 视 , N), (放 , DV), (在 , C), (桌 子 , N), (上 , LN)].

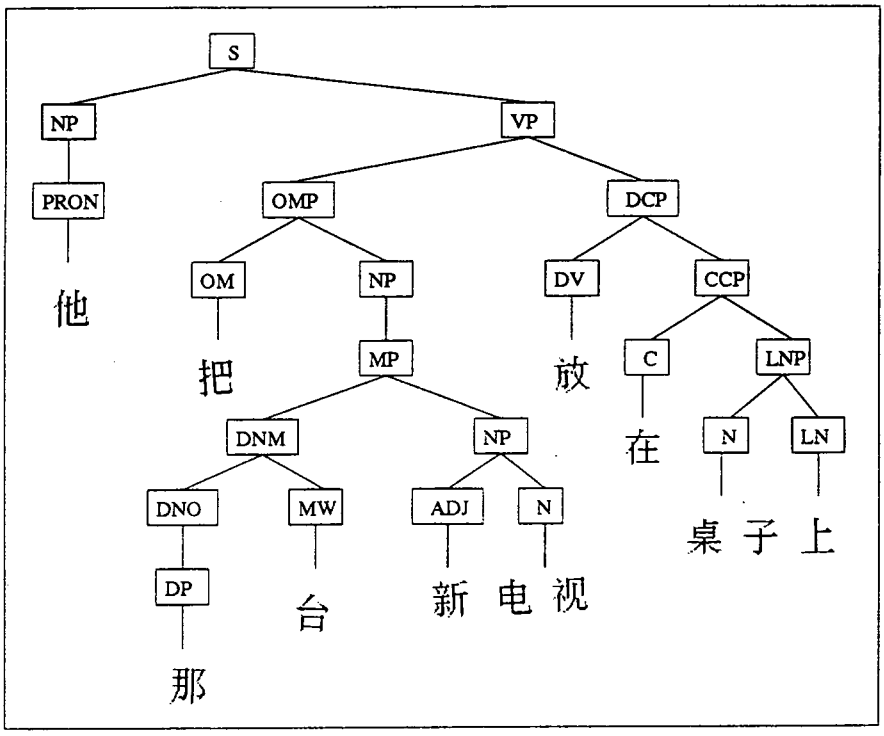

Figure 5.1: Parse Tree 1

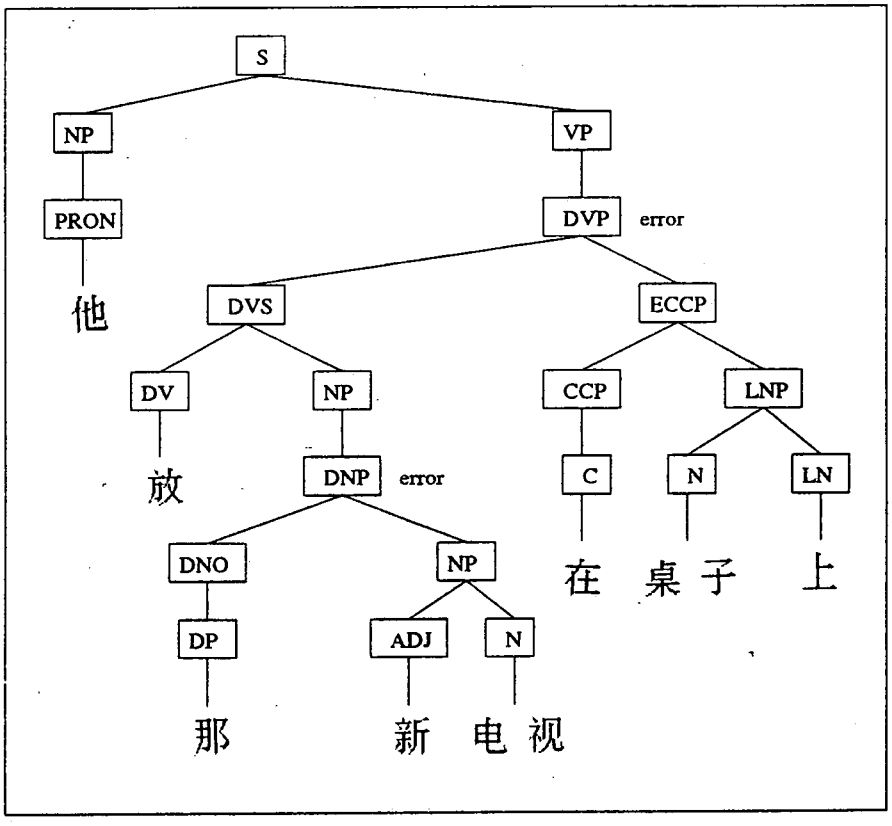

Figure 5.2: Parse Tree 2

After the grammatical categories of all the words in the input have been identified, the parser starts operating top-down. It searches the high-level syntactic structure expressed in the Mixed Grammar first. The final parsing result can be represented by *Parse Tree 1* [see *Figure 5.1*].

The English rules in the above examples have not been applied since the student's input can be parsed using the Chinese rules.

Example 2:

Chinese: 他 (he) 放 (put) 那 (that) 新 (new) 电 视 (tele) 在 (on) 桌子 (table) 上 (top).

The English meaning of Example 2 is the same as that of Example 1. However, in this case the Chinese input contains an error which can be interpreted as a transfer error. The result of bottom-up parsing for this input is:

[(他 , PRON), (放 , DV), (那 , DP), (新 , ADJ), (电 视 , N), (在 , C), (桌子 , N), (上 , LN)].

The result of top-down parsing can be represented by *Parse Tree 2* [see *Figure 5.2*]. The parser starts its top-down parsing by looking for an `S`, which needs an `NP` to begin with. The second noun phrase rule (Rule 3) matches, and therefore the parser moves on to look for a `VP`. It leaves a marker on Rule 19 (which is an English rule) as a site for possible backtracking later.

The parser tries Rule 14 in order to find a parse for the verb phrase. It looks for an `OMP` which needs a terminal `OM`. The parser fails to recognise an `OM` at that point, and the only thing that it can do is to backtrack to the marker, and therefore the English verb phrase (Rule 15) is applied.

Although `DVP` corresponds to an English construction (hence to an English rule), the student may enter correct Chinese forms for its constituents (`NP`, etc). This eventuality is catered for by ensuring that the constituents contain a Chinese rule where a Chinese equivalent exists. As usual these Chinese rules will be checked

first. For instance, the DVP construction is English, but the student may enter a Chinese noun phrase construction under DVS. As the parser checks the Chinese rules for NP first, this will be evaluated and the error will be located to the use of a DVS or DVP.

From the above description, it can be seen that the grammatical rules in the Mixed Grammar have been designed in a way which allow the parser to switch from Chinese to English rules and vice versa, as many times as necessary in order to detect complicated errors which could be interpreted as errors of transfer.

5.2.7 Automatic Detection of Transfer Errors

The English rules in the Mixed Grammar are used to pinpoint arbitrary transfer errors made by the students. As has been discussed in *Section 3.2*, there are three kinds of transfer error (word-order transfer, combinations of transfer, and partial transfer) which cannot be detected by the existing tools. However, the Chinese Tutor is capable of locating the above transfer errors using the rules in its Mixed Grammar.

Word-order transfer can be detected by the parser not only by looking at the transfer error identified, but also by checking its links with other constructs in the sentence.

Combinations of transfer errors can be pinpointed because the parser is able to switch from Chinese rules to English rules and vice versa as many times as necessary to fulfill the task of parsing a single input.

Partial transfer errors which satisfy part or most of an English rule can be detected using an optional function in the Mixed Grammar. For instance, in English, a relative clause can be formed in this way:

noun	+	relative pronoun	+	clause
the book		*that*		*I borrowed*

If the student has translated this relative clause into Chinese according to the English order but without the relative pronoun (书(book) 我 (I) 借 (borrow)), the parser can still identify it as an transfer error.

5.2.8 Detection Decides the Success of the Tutorial

It is of great importance for the parser of the Chinese Tutor to locate arbitrary transfer errors made by students. This is because of the following:

- The ultimate goal of the Chinese Tutor is to help students eliminate transfer errors, thus it is very important for a parser to locate automatically the possible transfer errors.
- The detection of transfer errors is the first but crucial step in ensuring a fruitful tutorial session.
- The tasks performed by the Diagnoser are based on the parsing result which has the English rule(s) marked. The Diagnoser infers from the parsing result the type(s) of transfer made by the student.
- Based on the diagnostic results, the Student Model will update the learning record if necessary by changing some of the values. For instance, the value for the error frequency will be increased by one if the student has made the same crucial mistake as before.
- The Tutor Model selects an appropriate tutorial strategy by referring to the diagnostic results (how serious the error is) and the updated Student Model (how often it has occurred). The Tutor Model will also choose an adequate example based on the rule marked in the parsing result, which caused the transfer error.

5.2.9 Possible Parsing Results

The following is a list of possible parsing results that can be generated by the parser using the grammatical rules in the Mixed Grammar:

1. a result marked with "TRANSFER ERROR";
2. a result marked with "NEW WORD";
3. a result with a broken parse tree;
4. a result with a complete parse tree (i.e. the input is a syntactically correct Chinese sentence);
5. a result marked with "TRANSFER ERROR" at more than one place;
6. a result with a combination of non-transfer errors (type 2 and 3);
7. a result with a combination of transfer errors (type 1 or 5) and non-transfer errors (type 2, 3 or 6).

5.2.10 Examples of Parsing Results

Some examples of possible parsing results generated by the parser are now given. They are examples of parse trees with a phrasal transfer error, with a syntactic transfer error, with a combination of a global transfer and a new word, with double transfer errors, with a broken parse tree, and with a complete parse. It will be the task of the Diagnoser to study the parsing results generated, and infer the types of error made by the student and how well the student has fulfilled his/her current task.

```
Parse Tree 1:
  chinese_sen
    prop_ph TRANSFER ERROR
      noun_per 教授 (Prof.)
      proper_per 张 (Zhang)
    prep_vp
      prep_ph
        prep 跟 (with)
        per_pronoun 我们 (us)
      trans_vp
        trans_v2 去 (go)
        propernoun 伦敦 (London)
```

Parse Tree 1 is a parsing result generated by the parser with a "TRANSFER ERROR" marked at the noun phrase level (i.e. the student has translated the noun phrase using the rule in the grammar of his/her native language). The correct translation for the noun phrase in Chinese should be in reverse: the title followed by the surname. The transfer error has been located by using an English rule in the Mixed Grammar. The English sentence for the student to translate is *Prof. Zhang will go to London with us.* The English translation (in brackets) in the parse tree has been added by hand in order to help the reader understand the parse tree better.

The parse tree shows that this is a *Chinese sentence* which is formed by an *proper noun phrase* and a *prepositional verb phrase.* The *proper noun phrase* consists of a *personal noun* followed by a *proper noun.* The *prepositional verb phrase* is made up of a *prepositional phrase*, which is a *preposition* followed by a *personal pronoun*, and a *transitive verb phrase*, which is a *transitive verb* followed by a *proper noun.*

```
Parse Tree 2:
  chinese_sen
    proper_per 约翰 (John)
    adverbial_vp TRANSFER ERROR
      trans_vp
        trans_v 吃 (have)
        common_n 午饭 (lunch)
      coverb_ph
        coverb 在 (at)
        common_n 学校 (school)
```

Parse Tree 2 is marked with "TRANSFER ERROR" at the *adverbial verb phrase* level because the student may have translated it according to the English word order *has lunch at school*, which is incorrect in Chinese. In Chinese, the *coverb phrase* normally precedes the verb phrase. The English sentence for the student to translate is *John has lunch at school.*

```
Parse Tree 3:
  interro_qu  TRANSFER ERROR
    interro_p 哪儿 (where)
    copula_vp
      copula 是 (is)
      associative_ph
        per_pronoun 她 (she)
        stru_ph
          stru_wd 的 ('s)
          propernoun 托车 NEW WORD
```

Parse Tree 3 is a parse tree with a combination of errors. The English sentence *Where is her motor bike?* seems to be translated entirely according to the English word order. Moreover, the parse tree is marked with "NEW WORD". The parser handles "NEW WORD", i.e. an unknown word by allocating it to any category that suits it. The correct Chinese translation should be 她的摩托车在哪儿?

```
Parse Tree 4:
  chinese_sen
    prop_ph TRANSFER ERROR
      noun_per 教授 (Prof.)
      proper_per 张 (Zhang)
    prep_vp  TRANSFER ERROR
      trans_vp
        trans_v2 去 (go)
        propernoun 伦敦 (London)
      prep_ph
        prep 跟 (with)
        per_pronoun 我们 (us)
```

Parse Tree 4 is a parsing result with a combination of transfer errors. The English sentence for translation is the same as for *Parse Tree 1.* However, the errors made are different from the first example. The student has made a double transfer error this time, one at the noun phrase level and the other at the verb phrase level.

```
Parse Tree 5:
  chinese_sen
    per_pronoun 我们 (we)
    trans_vp
      trans_v 学习 (study)
      common_n 汉语 (Chinese)
*cannot connect to the following:*
    trans_vp
      trans_v2 去 (go)
      propernoun 北京 (Beijing)
```

Parse Tree 5 is a broken parse tree marked in the middle with "*cannot connect to the following:*" (indicating that the student has made a syntactic error). What the student intended to say was 我们 去 北京 学习 汉语 (we go Beijing study Chinese) which in English is *We will go to Beijing to study Chinese.*

```
Parse Tree 6:
  chinese_sen
    prop_ph
      proper_per 刘 (Liu)
      noun_per 老 师 (Teacher)
    coverb_ph
      coverb 在 (is in)
      common_n 图 书 馆 (library)
```

Parse Tree 6 is a parse tree for a correct Chinese sentence, which means *Teacher Liu is in the library.*

The above parse trees show that the parsing results generated by the parser are clear in the sense that the transfer errors have been properly marked. The markings of transfer errors in the parse trees make it possible for the Diagnoser to infer the types of transfer error made by the student.

Chapter 6

The Student Model and the Diagnoser

No intelligent tutoring can take place without a certain understanding of the student. A Student Model models the student's ability based on the observed behaviour of a student [Sleeman 1990]. A Diagnoser provides diagnostic results by inferring types of error made by the student. These results are then used to reflect the current state of the student. The information collected by both models on the student's understanding of the domain knowledge as perceived by the system will be used to determine the appropriate instruction actions.

As has been discussed in *Section 3.2*, the only existing tool in language tutoring which claims to have a Student Model is **XTRA-TE**. However, how the Student Model of XTRA-TE undertakes its tasks is not sufficiently explained. Moreover, none of the existing tools have demonstrated how types of error made by the student are located.

A central concern of ITS is the diagnosis of students' errors and misconceptions [Sleeman 1982a]. Diagnosis of students' errors in an intelligent tutoring environment usually involves collecting a bug catalogue, as has been discussed in *Section 3.1.3*. The Student Model of the Chinese Tutor does not need to specify any errors.

This is because the grammar of the students' native language has been modelled. Moreover, the Diagnoser of the Chinese Tutor possesses a mechanism which is capable of inferring the types of error made by the student.

The Student Model of the Chinese Tutor fulfills the following tasks: collect information on how well the student has undertaken the current task; keep a record of the student's learning history; and update the learning record after each of the student's answers has been examined by the Diagnoser.

The Diagnoser of the Chinese Tutor classifies the types of error made by the student on the basis of the parsing result generated by the Expert Model, if the parsing result indicates the student's input contains some error(s). A list of classified results will be returned by the Diagnoser after the classification has been carried out. If the parsing result indicates no error has been made by the student, the Diagnoser will compare the student's translation with the possible standard ones in order to determine to what extent, his/her translation is correct. A list of comparison results will be returned after the comparison has been completed.

The reason for addressing the Student Model and the Diagnoser in the same chapter is that these two models are tightly interwoven, i.e. the diagnostic results are required by the Student Model for updating Student Model. Therefore, they must be discussed together.

In this chapter, we will discuss what kind of information needs to be gathered by the Student Model; how the information on the student's current performance is inferred and collected; and how a record of the student's learning history is kept.

6.1 Information Contained in the Student Model

The purpose of a Student Model is to provide information on the student's knowledge and skills, both correct and incorrect, so that the system's long-term decisions about planning his/her learning and the short-term decisions about what to do and

say next can be tailored to the benefit of the student [Vassileva 1990]. To allow the Chinese Tutor to make long and short-term decisions, its Student Model contains the following information:

- name of the student;
- lessons attempted;
- sentences attempted;
- the English sentences for translation;
- the student's answers;
- an error count indicating the frequencies of critical errors made within a lesson;
- latest classification results from the *Diagnoser*;
- latest comparison results from the *Diagnoser*;
- updated classification results;
- updated comparison results;

The reasons for maintaining such information are: *first*, by examining the information in the Student Model, the Tutor Model can determine how familiar the student is with the tutorial subject, what kind of help is required by the student, and how the system can adapt its instruction to the needs of the student; *second*, the information in the Student Model can provide teachers with some evidence of how language is learned and the strategies students employ in their target language learning; *third*, by looking at the previous tutorial sessions, students will be able to see the progress they made in overcoming mother tongue influence. This will also help them to strengthen their memory on how correct Chinese rules are formed.

6.2 Collecting Information on the Current Performance

In this section, for the sake of discussion, we have divided the process of information collection on the current performance of the student into three parts: Part One — information in relation to the current task; Part Two — diagnostic results from the Diagnoser; and Part Three — updated results from the Student Model.

6.2.1 Information in Relation to the Current Task

Information collected by the Student Model includes the *lesson* selected by the student for tutorial; the *number of the task*, within the specified lesson, given to the student; the current *English sentence* for translation; and the *student's translation.*

The *error count* in the Student Model is used for maintaining a table of the frequencies of critical errors, i.e. global transfer errors, syntactic transfer errors, syntactic errors and combinations of errors (with critical errors) within a lesson. It keeps track of how often a crucial error occurs. If the frequency of critical errors within a lesson is above a threshold, the Tutor Model will infer that extra help, such as additional exercises, should be assigned in the following tutorial session.

6.2.2 Diagnostic Results from the Diagnoser

An important issue in language tutoring is the classification of the types of error made by the student. This classification is used as a crucial means of revealing the weak-points of the student, thus providing the Tutor Model with accurate information on the student's performance and guiding the system's tutoring emphasis.

The Diagnoser studies the parsing result returned by the Expert Model — it checks the types of error produced if the parse tree indicates that errors have been

made, or compares the student's answer with the standard translation(s) if he/she has produced a correct Chinese sentence.

Types of Error Detected by the Diagnoser

As has been shown in *Section 5.2*, the main task of the parser is to detect arbitrary transfer errors and mark them in the parsing results. The parser also locates new words and indicates broken parse trees. In order to provide the system with accurate information on how serious the student's errors are, the Diagnoser needs to examine the parsing results generated by the parser and infer the types of error made.

Types of Transfer Error Inferred by the Diagnoser

The Diagnoser is able to identify the types of error detected in the students' test papers [see *Section 2.2.3*]. In order to provide the tutor model with more precise information on the general syntactic transfer errors, i.e. whether the whole sentence is syntactically incorrect, or only a part of it, global transfer errors have been introduced. A global transfer error occurs when the whole sentence is syntactically incorrect and the entire native language construction can be used to explain this kind of error. A syntactic transfer, however, covers other syntactic errors (such as word-order transfer) of mother tongue influence, i.e. errors in only part of a sentence. Let us look at an example of global transfer taken from the students' test papers.

- A Translation of a Sentence from English into Chinese with a Global Transfer Error.

English Sentence:

What kind of television will you buy?

Student's Translation:

什 么 种 电 视 要 你 买？

what kind TV will you buy

Comments: Some students carried out a word-for-word translation for the entire sentence, which leads to a syntactic error in the target language.

Correct Translation:

你 要 买 哪 种 电 视？

you will buy which kind TV

If the parsing result is marked with "TRANSFER ERROR", it indicates one of the following diagnostic results:

- the input contains a lexical transfer error;
- the input contains a phrasal transfer error;
- the input has a syntactic transfer error;
- the input contains a global transfer error.

Types of Non-Transfer Errors Diagnosed

If the parsing result is marked with "NEW WORD", it indicates either a lexical error (the choice of a wrong character) or a new word which is beyond the Chinese dictionary. A broken parse tree generated by the parser suggests a pure syntactic error.

Combinations of Errors Located

The parsing result can also indicate a combination of errors. The diagnostic results for the combination of errors can be one of the following:

- the input contains a combination of transfer errors;

- the input has a combination of non-transfer errors;
- the input contains a combination of transfer error(s) and non-transfer error(s).

Inferring Types of Error from the Parsing Result

The student's translation is either a good parse, i.e. a correct Chinese sentence, in which case a comparison result is returned, or is a bad parse, in which case types of the error are returned as a list of classified results. In both cases, the result also contains a value indicating whether a rule is mastered. The method used by the Diagnoser for carrying out its comparison will be addressed in the next section *Comparison between the Student's Answer and the Standard Translations.*

The Diagnoser examines the parsing result in a top-down mode, in its search for the markings of "NEW WORD" or "cannot connect to the following" (a broken parse tree) or "TRANSFER ERROR".

If the parse tree is marked with "NEW WORD", it will be detected as a lexical error. If the parse tree is broken, it indicates a pure syntactic error which has nothing to do with transfer. The detection of lexical errors or syntactic errors is quite straight forward, compared with that of transfer errors. The diagnosis of transfer errors is much more complicated since the Diagnoser needs to infer the type of transfer from the parsing result.

The Diagnoser detects the types of transfer error by examining at which level the parse tree has been marked with "TRANSFER ERROR". If "TRANSFER ERROR" has been indicated at the root of the parse tree, it suggests a global transfer error. The Diagnoser will substitute "TRANSFER ERROR" marked on the parse tree, with "GLOBAL TRANSFER", extract the rule which lies behind the transfer error, and give the rule together with the type of transfer error to the Student Model for inclusion.

If "TRANSFER ERROR" is marked at the verb phrase level, it indicates a syntactic transfer error, the feature "TRANSFER ERROR", on the parse tree,

will be changed and the result will be given to the Student Model accordingly.

If "TRANSFER ERROR" is marked at the noun phrase level or at the subtree of which noun phrase or verb phrase is the root, it indicates a phrasal transfer error.

Comparison between the Student's Answer and the Standard Translations

When the parsing result generated by the parser contains no features, i.e. "TRANSFER ERROR", "NEW WORD" or a message indicating a broken parse tree, it means that the student has keyed in a correct Chinese sentence. This, however, does not necessarily mean that the student has correctly translated the sentence. In order to determine to what extent the student has translated the sentence correctly, a comparison is needed between the student's translation and the standard translations.

The comparison result given by the Diagnoser can be one of the following: `excellent`, `good`, `average`, `below average` or `poor`. The student's translation is `excellent` when it matches one of the standard translations for a particular task stored in the system. When the student has translated most parts of the sentence correctly (the best score achieved when matching the input with each of the standard translations is 80% or above), the comparison result will be `good`. If the best score achieved for the translation is between 60% and 79%, the result will be `average`. The comparison result will be `below average` when the best score is between 40% and 59%. The student's translation is `poor` when the best score is below 40%.

The Diagnoser possesses a mechanism for efficiently undertaking its comparison tasks. A special notation for combining the possible standard translations for an English sentence into a single string has been used to speed up the comparison process. For instance, for the English sentence *I will buy an Arabic dictionary in the book shop*, there are over 30 ways of translating it based on the knowledge that

the student could have learned from the two textbooks. It would be inefficient for the Diagnoser to go through all the standard translations line by line.

The notation is used when there are no dependences between the various possibilities. The special notation used in the Chinese Tutor is square brackets separated by a comma, indicating a choice, and round brackets, suggesting that a word or part of a word can be omitted. The following shows the possible ways of translating the English sentence above. It is represented by a single string instead of over 30 lines of possible standard translations.

我 (要) [在 ,去] 书 店 买 (一) 本 (儿) [阿 拉 伯 文 , 阿 拉 伯 语] 词 典 .

Rule Mastered

The diagnostic results indicate whether the student has mastered a particular grammatical rule. If the student has produced a correct Chinese sentence and the result of the comparison shows that he/she has successfully fulfilled his/her task, this lesson will be considered as 'mastered' by the student. If the student has made some mistakes in his/her translation or if the translation has not matched completely with any of the possible standard translation, the lesson will be considered as 'unmastered'.

Example Diagnostic Results

Some examples of diagnostic results generated by the Diagnoser will be shown in this section. The same examples as shown in *Section 5.2.10* on parsing results will be used to show how the Diagnoser detects types of error on the basis of the results generated by the parser. Comments on each parse tree are also given.

```
Parse Tree 1:
  chinese_sen
    prop_ph PHRASAL TRANSFER
      noun_per 教授 (Prof.)
      proper_per 张 (Zhang)
    prep_vp
      prep_ph
        prep 跟 (with)
        per_pronoun 我们 (us)
      trans_vp
        trans_v2 去 (go)
        propernoun 伦敦 (London)
```

Bad parse:

Classified Result: (prop_ph, PHRASAL TRANSFER)

ruleMastered: unmastered

Comments on Parse Tree 1: The Diagnoser infers that the student has made a phrasal transfer error. It extracts the rule that lies behind the transfer and passes this together with the type of error on to the Student Model. Since the student has made a transfer error, it indicates that this particular grammatical rule has not been mastered.

```
Parse Tree 2:
  chinese_sen
    proper_per 约翰 (John)
    adverbial_vp SYNTACTIC TRANSFER
      trans_vp
        trans_v 吃 (have)
        common_n 午饭 (lunch)
      coverb_ph
        coverb 在 (at)
        common_n 学校 (school)
```

Bad parse:

Classified Result: (adverbial_vp, SYNTACTIC TRANSFER)

ruleMastered: unmastered

Comments on Parse Tree 2: The Diagnoser classifies the transfer error detected by the Expert Model as a syntactic transfer error because it occurs at the verb phrase level. The diagnostic result also shows that the student has not mastered this grammatical rule.

```
Parse Tree 3:
  interro_qu  GLOBAL TRANSFER
    interro_p 哪儿 (where)
    copula_vp
      copula 是 (is)
      associative_ph
        per_pronoun 她 (she)
        stru_ph
          stru_wd 的 ('s)
          propernoun 托车 LEXICAL ERROR
```

Bad parse:

Classified Result: (interro_qu, GLOBAL TRANSFER)

(propernoun, LEXICAL ERROR)

ruleMastered: unmastered

Comments on Parse Tree 3: This is a parse tree with a combination of errors. The student has made a global transfer error and a lexical error, according to the diagnostic results. The Diagnoser extracts the rule and the word which is incorrect and infers that this grammatical rule has not been mastered by the student.

```
Parse Tree 4:
  chinese_sen
    prop_ph PHRASAL TRANSFER
      noun_per 教授 (Prof.)
      proper_per 张 (Zhang)
    prep_vp  SYNTACTIC TRANSFER
      trans_vp
        trans_v2 去 (go)
        propernoun 伦敦 (London)
      prep_ph
        prep 跟 (with)
        per_pronoun 我们 (us)
```

Bad parse:

Classified Result:(prop_ph, PHRASAL TRANSFER)

(prep_vp, SYNTACTIC TRANSFER)

ruleMastered: unmastered

Comments on Parse Tree 4: This is an example with double transfer errors. The first transfer error, which appears at the noun phrase level, is a phrasal transfer error; while the second, which occurs at the verb phrase level, is a syntactic transfer.

```
Parse Tree 5:
  chinese_sen
    per_pronoun 我们 (we)
    trans_vp
      trans_v 学习 (study)
      common_n 汉语 (Chinese)
*cannot connect to the following:*
      SYNTACTIC ERROR
    trans_vp
      trans_v2 去 (go)
      propernoun 北京 (Beijing)
```

Bad parse:

Classified Result: (trans_vp, SYNTACTIC ERROR)

ruleMastered: unmastered

Comments on Parse Tree 5: The Diagnoser examines the parse tree and infers that a syntactic error has been made. Thus, the grammatical rule of this lesson has not been grasped by the student.

```
Parse Tree 6:
  chinese_sen
    prop_ph
      proper_per 刘 (Liu)
      noun_per 老师 (Teacher)
    coverb_ph
      coverb 在 (is in)
      common_n 图书馆 (library)
```

Good parse:

Comparison Result: (coverb_ph, excellent)

ruleMastered: (coverb_ph, 1)

Comments on Parse Tree 6: This is a complete parse tree, therefore the Diagnoser compares the student's input with the standard translations. The comparison result is excellent: the student has translated the sentence correctly. The Diagnoser then extracts the rule at the verb phrase level, since this exercise is to practise the use of coverbs in Chinese. The value of ruleMastered indicates that the student has mastered the lesson.

6.2.3 Updated Results from the Student Model

The updated Student Model provides a general view on how well the student has performed so far, i.e. how familiar he/she is with the tutorial subject. It also

provides detailed information on the number of times the student has mastered a particular rule within a lesson, and how often he/she has made a certain type of error. The updated Student Model gives crucial information to the Tutor Model on the student's current state of learning.

The Student Model is updated after each of the student's translations has been parsed, and the result has been examined by the Diagnoser. One of two values will be updated in the Student Model: either the frequency table (if the diagnostic result indicates that errors have been made), or the familiarity of a rule (if that rule has been mastered).

6.3 Keeping a Record of the Learning History

The Student Model of the Chinese Tutor keeps a record of the learning history of a student. The main purpose for keeping such a record is that it provides the Tutor Model with accurate information on the student's performance, both current and general, and makes it possible for the system to tailor its instruction to the needs of the student.

The student's learning history consists of the lessons attempted, the sentences attempted, the translation exercises, the student's answers, the diagnostic results, the updated results of classification and comparison, and the error count. This list records all of the present and past performances of the student, with the head of the list being his/her most recent performance. Let us look at an example of a record from the learning history.

****

Student's Name: Wang Yang

Lesson Specified for Tutorial: Lesson 17

Number of Task: 2, 1

English Sentences for Translation:

(2) We are going to the Great Wall tomorrow morning at 11.

(1) He gets up at 8 every day.

Student's Translations:

(2) 我 们 打 算 明 天 早 上 十 一 点 去 长 城 .

(1) 每 天 他 起 床 八 点 .

Diagnostic Results:

(2) Comparison Result: (time_adverbial_vp, excellent)

ruleMastered: (time_adverbial_vp, 1)

(1) Classified Result: (en_time_adverbial_vp, SYNTACTIC TRANSFER)

ruleMastered: unmastered

Updated Results:

(2) Updated Comparison Result: (time_adverbial_vp, 1)

(1) Updated Classified Result: (en_time_adverbial_vp, 1)

Error Count:

(en_time_adverbial_vp, 1)

In this chapter, the tasks undertaken by the Student Model and the Diagnoser have been discussed. The information provided by these two models will be used by the Tutor Model to select an appropriate tutorial strategy which can meet the needs of a particular student.

Chapter 7

The Tutor Model

The idea of how to communicate knowledge is another important ingredient in Intelligent Language Tutoring Systems, and is represented as a Tutor Model. Until recently, the idea that this didactic knowledge could be explicitly represented in tutoring systems had been paid less attention than the representation of the subject matter. This is probably because pedagogy itself is more complex and more difficult to represent than most of the subjects to which it is applied [Wenger 1987a].

The Tutor Model of the Chinese Tutor is in charge of the instructional activities: in particular, choosing an appropriate tutorial strategy based on the observed behaviour of the student. At the global level, the didactic decisions affect the sequence of didactic episodes. At the local level, the tutor determines which tutorial strategy is suitable. The Tutor Model is the model that communicates (via the Interface Module) with the student, providing exercises, monitoring and commenting on his/her performance, offering assistance and selecting remedial material.

As has been addressed in *Section 3.1.3* on the *Design Issues of ITSs*, the designers of some ITSs such as WHY, claim that their systems could help students to solve problems using the Socratic method. Research into dialogue theory has been investigated only in the recent years. Therefore, it is debatable as to whether the WHY program could carry out real dialogues. The Socratic method is good,

however, it is beyond the state of the art to implement it.

As has been discussed in *Section 3.2.1*, there are only three tools (ALICE, XTRA-TE and Schwind's ILTS) which claim to have tutor modelling. However, the drawbacks of the existing tools in the selection of a tutorial strategy can be summarised in two particular aspects. *Firstly*, the existing tools lack sophistication in determining which tutorial strategy should be used, i.e. the decisions are made on the basis of the overall performance of all the rules, without taking into account the local information on how well a particular kind of task is carried out. *Secondly*, the tutorial strategy is not flexible: the student is offered the same tutorial strategy even though errors of the same kind may have occurred before.

A challenging issue in language tutoring, is how to tailor the tutorial strategy to the needs of a particular student. According to the experts' views on Chinese teaching and personal teaching experience of Chinese, a language tutoring system can adapt its instruction to the needs of the student better if the system is capable of choosing a tutorial strategy on the basis of both the student's current and general performance, on the mastery of a particular kind of task. A system with this ability can provide the student with more helpful and adequate advice and assistance than systems that have little knowledge about how the student has previously carried out a particular task.

In this chapter, four important issues in relation to tutor modelling will be addressed. First of all, we will focus on the basis for the design of the Tutor Model; then will move on to how the Tutor Model plans learning for the student; how the didactic decisions are made; and finally how the Tutor Model adapts its instruction to the needs of the student.

7.1 Basis for the Design of the Tutor Model

The design of the Tutor Model has been based on the results collected from formal [see *Appendices A & B*] and informal knowledge acquisition, focusing on the

techniques human teachers apply in helping their students to solve the problem of negative transfer. The informal interviews also include how tutorial plans should be made, and how tutorial strategies should be formed and selected. The design of the Tutor Model has also been based on personal experience of Chinese teaching.

As shown in the questionnaire [see *Appendix B*], a useful technique applied by teachers to assist their students in overcoming mother tongue influence, is to explain to the student the causes of errors, by comparing the grammatical rule in the target language with the corresponding rule in the native language. Using comparisons, the student can easily see the difference or similarity between the two rules. The technique of comparing the grammar of the target language and the grammar of the native language has been implemented in the tutorial strategies of the Tutor Model.

Another useful technique we discovered through the informal interviews and through personal teaching experience, in helping students eradicate transfer errors, is to provide the student with flexible tutorial strategies, the selection of which should be based on the frequency of a critical error. For instance, if the student makes an error (e.g. global transfer) for the first time, a hint could be given. The student should be informed that he/she has translated the sentence according to the English sentence structure, which is wrong in Chinese. If the student cannot work out which part of the translation went wrong and makes the critical transfer error again, the student should be provided with a detailed explanation of the error, some examples to illustrate the grammatical point, and standard translations for helping him/her understand the mistake thoroughly. Most of the students will be able to grasp the rule after the detailed explanations. However, for students whose learning of Chinese grammar has been greatly affected by the grammar of their native language, the same error could be made for a third time. If this happens, the student will be reminded of what has been explained in the previous tutorials. This whole set of graded tutorial strategies has also been implemented in the Tutor Model.

If the student makes consistent critical errors, this indicates that additional

help is needed. The student should be given some simpler exercises, rather than translation exercises, to ensure that he/she knows the basic structure of a particular rule. Two additional tutorial strategies (strategies for pair choice exercises and sentences built up from constituents) have also been implemented in the Tutor Model to deal with these simpler exercises.

7.2 Tutorial Plans

The tutorial plans of the Chinese Tutor contain the ultimate goal of the tutorials; the selection of a tutorial strategy; flexibility in applying tutorial strategies; additional tutorials; and new lessons.

7.2.1 Ultimate Goal of the Tutorials

The ultimate goal of the tutorials provided by the Chinese Tutor is to help first-year students to grasp the important grammatical rules which they find difficult and fail to master.

Based on the empirical data, 17 lessons (24 grammatical points) [see *Chapter 5.1.2*] have been chosen for tutorials. These lessons cover all of the key grammatical rules which can be used to explain a considerable number of transfer errors among students. Therefore, if the student makes fewer transfer errors after interacting with the Chinese Tutor, this indicates, on the one hand, that the system has been successful in helping students overcome mother tongue influence, and on the other hand, that the student's standard of Chinese has been improved.

In order to achieve the tutorial goals, i.e. eradicating transfer errors, a great number of translation exercises, additional exercises, standard translations, examples and tutorial strategies have been designed under each grammatical point. The 17 lessons include both simple grammar points (such as *Lesson 6* [see *Chapter 5.1.2*]) and complicated ones (such as *Lesson 44* and *Lesson 54* [see *Chapter 5.1.2*]).

The translation exercises have been designed to elicit transfer errors. These exercises will effectively lead to the mastery of the Chinese rules which the students have failed to grasp. Moreover, these exercises will prevent students from avoiding some of the grammatical rules which they are not confident about, and which could lead to transfer errors. This is because the strategy of *avoidance* is common among second language learners [see *Section 2.1.4* on *Language Transfer Re-Examined*].

Additional exercises can help students to grasp the basic structure of a particular grammatical rule after several unsuccessful attempts have been made in the translation exercises. The possible standard translations for all of the translation exercises are used to show how correct translations are constructed when errors are made by the students, and what the alternative correct translations are. Examples are used to help students by illustrating a specific grammatical rule, thus providing students with an alternative expression, and at the same time reinforcing their memory on the correct structure of a particular type of rule. The normal and additional tutorial strategies provided by the Chinese Tutor are tailored to the needs of the students, thus making it possible for students to overcome mother tongue influence effectively.

7.2.2 Choice of a Tutorial Strategy

One of the main drawbacks of the existing tools in tutor modelling for language tutoring, as has been addressed in *Section 3.2.1* on *Tutorial Strategies* and summarised at the beginning of this chapter, is the lack of sophistication in the choice of tutorial strategies. The selection of an appropriate tutorial strategy determines the success of the whole tutorial session, thus it is of great importance for a language tutoring system to be able to deliver the appropriate help [Burns 1988].

The selection of a tutorial strategy in the Chinese Tutor is determined by the kind of help required by the student, which is indicated by the diagnostic results (the type of error made), the updated results (how many times this particular kind of error has occurred) and the evaluation results (how serious an error is). By

reacting to the student's current and general performance, on the mastery of a particular kind of grammatical rule, the Tutor Model can adapt its instruction to the needs of the student, by providing him/her with informative and helpful feedback. This approach is more sophisticated than that of, e.g. XTRA-TE, in which the choice of a tutorial strategy is based only on the student's overall performance in learning all of the rules.

7.2.3 Flexible Tutorial Strategies

The other main drawback of the existing tools, in tutor modelling, is the lack of flexibility in the use of tutorial strategies. Schwind's ILTS has the same routine for helping the student, no matter how serious the error is or how often a specific type of error has been made. If a system cannot provide flexible tutorial strategies, it is hard to keep the student motivated and ensure a fruitful tutorial session.

The Tutor Model of the Chinese Tutor is capable of providing various kinds of tutorial strategy, the selection of which is based on the diagnostic results, the updated results and the evaluation results. For instance, if the student had made a critical transfer error in the previous translation, the Tutor Model will select a different, but appropriate, tutorial strategy the next time.

7.2.4 Additional Tutorials

Additional tutorials have been designed to help students whose learning of Chinese grammar has been greatly affected by the sentence structures of English. The student demonstrates that extra help is required when the student has made some consistent critical transfer errors. There are two series of additional tutorials (tutorials on pair choice exercises and sentences built up from constituents) provided by the Tutor Model when the above situation occurs.

The Tutor Model first gives the student a series of pair choice exercises to check

whether he/she can identify the correct Chinese sentence from an incorrect one. The student will be given more pair choice exercises until he/she is familiar with the exercises. If the student can follow the pair choice exercises, he/she will be given a series of sentences built up from constituents and asked to form a correct sentence using the constituents. This series of exercises is used to help the student master the basic structure of a particular rule. If the student can cope with that, he/she will be given more translation exercises which will gradually lead him/her back to the current stage of learning.

7.2.5 Starting a New Lesson

When the comparison result from the Diagnoser shows that the student has translated the current task correctly, this indicates that the rule has been mastered by the student. In order to ensure that the student is familiar with the current tutorial topic, he/she will be asked to do a similar task once more. Once the student has demonstrated that he/she is capable of fulfilling the tasks twice within a lesson, he/she will be asked to start another lesson.

7.3 Didactic Decisions

The didactic decisions are decisions made by the Tutor Model for determining what kind of help is required by the student and how the appropriate help can be delivered. The didactic decisions are made automatically by examining the error count, the diagnostic results and the updated Student Model. *Figure 7.1* shows how these decisions are made by the Tutor Model.

After the Diagnoser has fulfilled its tasks and the Student Model has been updated, the Tutor Model starts analysing the results provided by the Student Model and the Diagnoser in order to decide what the next appropriate course of action is. The following explains how the Tutor Model makes its didactic decisions.

The Tutor Model first checks the information provided by the *error count* for the frequency of critical errors made by the student in the previous tutorial sessions. If the frequency is below the threshold, (i.e. errors made are not (yet) consistent), the Tutor Model will give the student normal tutorials and one of the *normal strategies* will be applied. In contrast, if the frequency is above the threshold, which indicates that consistent errors have been made, an additional tutorial (i.e *additional strategies*) will be employed.

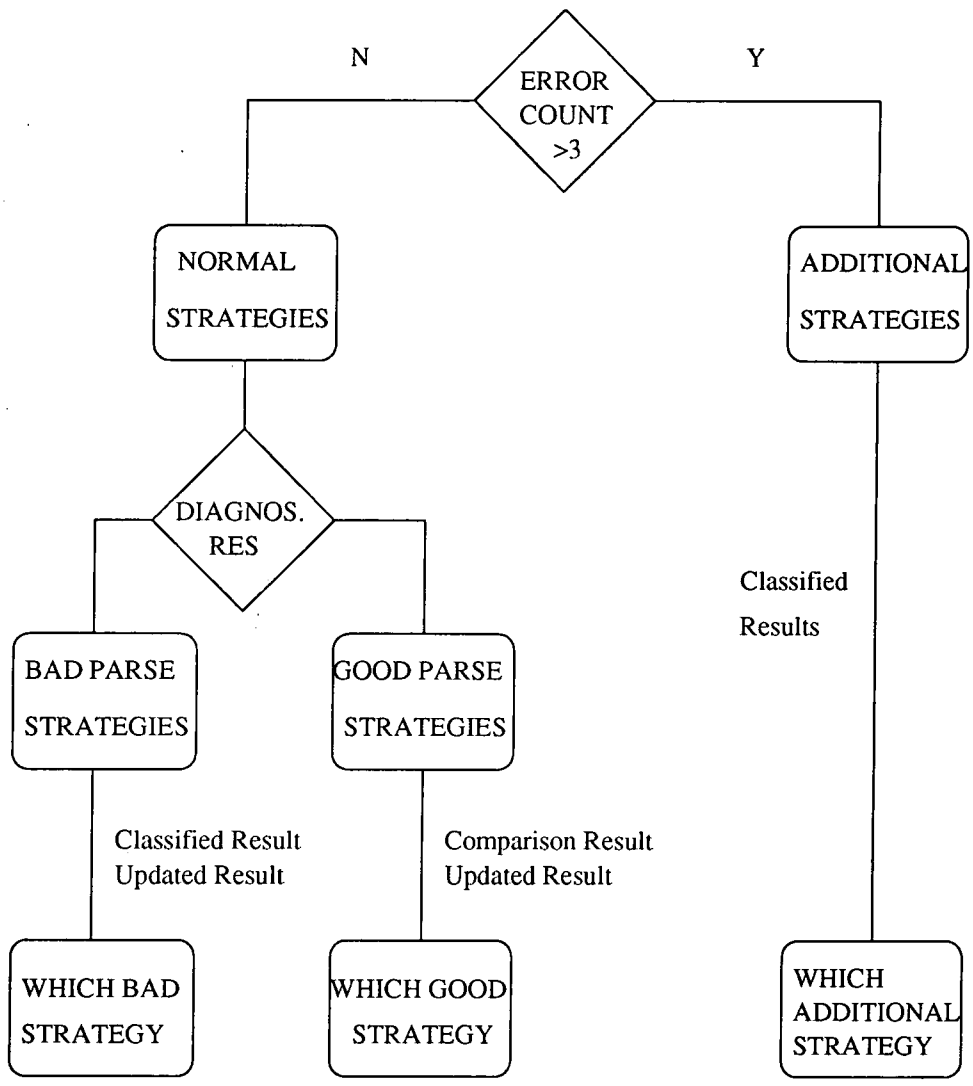

Figure 7.1: The Didactic Decision Making Process of the Tutor Model

If the Tutor Model decides that a normal tutorial is to be given, it will check the *diagnostic results* to see whether any errors have occurred in the current performance of the student. If the results indicate that errors have been made (i.e. a bad parse), the Tutor Model will select a *bad parse strategy* which is designed to cope with the type(s) of error in the student's input. In contrast, if the student has produced a correct Chinese sentence, the Tutor Model will choose a *good parse strategy* for commenting on his/her performance.

Detailed explanations will be given in the next section of how a particular bad parse strategy, good parse strategy and additional tutorial strategy are selected.

7.4 Tutorial Strategies

The Tutor Model is equipped with 17 normal tutorial strategies and 2 additional tutorial strategies. The tutorial strategies in the Chinese Tutor have been designed on the basis of useful techniques employed by experts in helping their students overcome mother tongue influence, and personal teaching experience of Chinese.

The normal tutorial strategies are used to cope with arbitrary transfer errors and non-transfer errors made by the student, which include strategies both for simple and complicated errors. In the normal tutorial strategies, the Tutor Model gives comments on the student's performance, provides him/her with standard translations and examples, and explains where and why the translation has gone wrong. The standard translations, examples and explanations are selected automatically by a standard translation selector and an example selector respectively.

The additional tutorials provided by the Tutor Model are used for helping the student to grasp the grammatical rules which he/she may have found difficult. The Tutor Model provides the student with a series of additional tutorials when he/she is engaged in doing additional exercises on a particular kind of problem.

In this section, we will first address how a normal and additional tutorial strat-

egy are selected by the Tutor Model. We will then move on to issues in relation to how a particular strategy is formed; and finally some examples of normal strategies will be given. The additional tutorial strategies can be seen in *Section 8.4*.

7.4.1 Normal Tutorial Strategies

The normal tutorial strategies have been designed based on useful techniques employed by experts in helping their students overcome errors of transfer. These strategies in the Tutor Model are further divided into two main groups: *bad parse strategies* and *good parse strategies*. The bad parse strategies consist of two sub-groups: strategies for critical errors and strategies for non-critical errors. Critical errors include global transfer errors, syntactic transfer errors and syntactic errors.

Bad Parse Strategies

The reason for dividing bad parse strategies into two sub-groups is that critical errors are more important than non-critical errors and can affect a great number of cases, and therefore, should be handled with more care.

A bad parse strategy for critical errors is selected according to three kinds of result: diagnostic results on the types of error made; updated results on the frequency of a particular type of error; and the results of the evaluation determined by the Tutor Model on the generality of an error [see *Table 7.1*]. A bad parse strategy for non-critical errors is chosen on the basis of the diagnostic results and the results of the evaluation [see *Table 7.2*].

The Tutor Model evaluates the student's performance using the principle of *generality* to define a hierarchy of errors. Generality in language learning is used to measure how serious an error is.

TYPES OF ERROR	FREQUENCY	GENERALITY	STRATEGY
SYNTACTIC TRANSFER or GLOBAL TRANSFER	ONCE	HIGH	COACHING TO HANDLE TRANSFER (1)
SYNTACTIC TRANSFER or GLOBAL TRANSFER	TWICE	HIGH	COACHING TO HANDLE TRANSFER (2)
SYNTACTIC TRANSFER or GLOBAL TRANSFER	THREE TIMES	HIGH	COACHING TO HANDLE TRANSFER (3)
(SYNTACTIC TRANSFER or GLOBAL TRANSFER) & OTHER ERRORS	ONCE	HIGH	COACHING TO HANDLE COMBINATIONS OF TRANSFER (1)
(SYNTACTIC TRANSFER or GLOBAL TRANSFER) & OTHER ERRORS	TWICE	HIGH	COACHING TO HANDLE COMBINATIONS OF TRANSFER (2)
(SYNTACTIC TRANSFER or GLOBAL TRANSFER) & OTHER ERRORS	THREE TIMES	HIGH	COACHING TO HANDLE COMBINATIONS OF TRANSFER (3)
SYNTACTIC ERROR	—	HIGH	COACHING TO HANDLE SYNTACTIC ERROR
SYNTACTIC ERROR & OTHER ERRORS	—	HIGH	COACHING TO HANDLE COMBINATIONS OF SYNTAX

Table 7.1: Bad Parse Strategies for Critical Errors

TYPES OF ERROR	GENERALITY	STRATEGY
PHRASAL TRANSFER	MEDIUM	CORRECTION OF PHRASAL TRANSFER
COMBINED PHRASAL TRANSFER	MEDIUM	CORRECTION OF COMBINED PHRASAL TRANSFER
COMBINATIONS OF MID & LOW GENERALITY	MEDIUM	CORRECTION OF COMBINED NON-CRITICAL ERRORS
LEXICAL ERROR	LOW	CONFIRMATION
COMBINATIONS OF LEXICAL ERRORS	LOW	CORRECTION OF COMBINED LEXICAL ERRORS

Table 7.2: Bad Parse Strategies for Non-Critical Errors

The student's errors are divided into three categories: *high generality*, *medium generality* and *low generality*. An error involving *high generality* (i.e. critical errors) reveals a weakness that may affect an indefinite number of cases and may therefore have more serious consequences than errors of lower generality.

There are two sets of bad parse strategies for coaching critical transfer errors, the selection of which is determined by the frequency of the error. If the student has made a critical transfer error for the first time, the strategies of either *Coaching to Handle Transfer (1)* or *Coaching to Handle Combinations of Transfer (1)* will be applied, depending on whether a single transfer, or a combination of a critical transfer error and non-critical error(s) has occurred. If the above kinds of error have been made for the second time, the corresponding coaching strategy (*Coaching to Handle Transfer (2)* or *Coaching to Handle Combinations of Transfer (2)* will be given, and until the fourth iteration where additional tutorial is given. The frequency of syntactic errors, or a combination of a syntactic error and other errors is not as important as that of critical transfer errors, as the former contribute only a small percentage of the critical errors in the test papers.

For non-critical errors, different correction strategies and a strategy of confirmation have been designed. If a phrasal transfer error has been identified by the Diagnoser, the evaluation by the Tutor Model on the student's current performance will be of *medium generality*, and the strategy of *Correction of Phrasal Transfer* will be provided. If a double phrasal transfer (i.e. a combination of phrasal transfers) has been made, the strategy of *Correction of Combined Phrasal Transfer* will be used. If the student's errors are of a combination of *medium* and *low generality*, *Correction of Combined Non-Critical Errors* will be selected. The strategy of *Confirmation* will be applied when the student has made only a single lexical error in the translation. The strategy of *Correction of Combined Lexical Errors* is for dealing with a combination of lexical errors.

Good Parse Strategies

A good parse strategy is selected based on the comparison results provided by the Diagnoser: if the comparison result is *excellent*, the strategy of *approval* will be given; if the result is *good*, *suggested alterations* will be used; if the result indicates *average*, *correction* will be applied; and if the result is *below average*, the strategy of *assistance* will be given.

7.4.2 Additional Tutorial Strategies

The selection of an additional strategy is on the basis of the types of consistent error indicated by the error count. When the Tutor Model decides that an additional tutorial is required, strategies for pair choice exercises will be applied. Once the student has demonstrated his/her ability in pair choice exercises, he/she will be moved on to sentences built up from constituents, and therefore strategies for this type of exercise will be provided.

7.4.3 Construction of a Particular Strategy

When the Tutor Model has decided which normal tutorial strategy is to be given to the student, a tutorial strategy constructor will form a proper tutorial strategy after collecting information from various sources, which include the strategy content, an example and its explanation chosen by an example selector, and possible standard translations selected by a standard translation selector. An exercise selector will then assign another suitable exercise for the student to do. The domain knowledge required by each tutorial strategy is selected on the basis of the observed behaviour of the student.

An appropriate normal tutorial strategy is constructed automatically each time, once the system has decided which strategy will be used. A template structure is used for constructing a normal strategy. Certain parts of the template will be

substituted with appropriate information (e.g. standard translations, examples and explanations).

The construction of additional tutorial strategies is not as complicated as that of the normal strategies. Because of the nature of the pair choice exercises and the sentences built up from constituents, the student's answer can be judged as either correct or incorrect. Therefore, the additional strategies could be pre-stored in a data file.

7.4.4 Examples of Tutorial Strategies

In order to provide the reader with a better understanding of the tutorial strategies of the Chinese Tutor, a number of examples have been selected from both bad parse strategies and good parse strategies. They demonstrate how the strategy constructor collects all the necessary information for a particular tutorial strategy. The bad parse strategies are *Coaching to Handle Transfer (2)* and *Correction of Combined Phrasal Transfer*, while the good parse strategies are *Assistance* and *Approval*. We will look at first how the strategies are stored in the template and then how the strategy constructor collects all the relevant information.

The strategies have been stored in the template according to the following format. The % sign preceding words such as Example or CorrectTranslation in the template indicates that a suitable example or a correct translation will be assigned by the example selector and the standard translation selector respectively, once a tutorial strategy has been selected.

```
Strategy: Coaching to Handle Transfer (2)

I'm sorry to inform you that you have translated the sentence accord-
ing to the English word order again. You may find that there is more
than one way of translating the sentence: %CorrectTranslation Here
is an example to help you: %Example Bearing this in mind, try again!

Strategy: Correction of Combined Phrasal Transfer

You have translated two phrases according to the English pattern,
```

which is not correct in Chinese. The sentence may be translated in the following ways: %CorrectTranslation Here are some examples of Chinese phrases to help you: %Example

Strategy: Assistance

You have produced a Chinese sentence,but it is not a correct translation of the English sentence. The sentence can be translated in the following ways: %CorrectTranslation

Strategy: Approval

I am pleased to tell you that your translation is correct. Well done!

After the strategy constructor has collected all the relevant information, the strategies will look like the following:

Strategy: Coaching to Handle Transfer (2)

I'm sorry to inform you that you have translated the sentence according to the English word order again. You may find that there is more than one way of translating the sentence:

我 姐姐 在 西班牙 学 历史 or

我 姐 在 西班牙 学习 历史 .

Here is an example to help you:

他 在 图书馆 借 一 本 书 .

The prepositional phrases formed with the coverb in Chinese normally precede the predicates (prepositional phrase + predicate). This is different from the word order in English, in which prepositional phrases follow predicates (predicate + prepositional phrase).Bearing this in mind, try again!

COMMENTS: COACHING TO HANDLE TRANSFER (2)

This is the second time that the student has made a critical transfer error. The English sentence for the student to translate is: *My elder sister studies history in Spain.*

Strategy: Correction of Combined Phrasal Transfer

You have translated two phrases according to the English pattern, which is not correct in Chinese. The sentence can be translated in the following ways:

刘 老师 要 买 哪 本 词典 or

刘 老师 要 买 哪 一 本 词典 .

Here are some examples of Chinese phrases to help you:

(1) 张 教授

In Chinese, a title (such as: 老师 or 医生) normally follows a surname. This is different from English where one says: title + surname.

(2) 哪 个 大夫

Don't forget that there should be a measure word between an interrogative pronoun and a noun.

COMMENTS: CORRECTION OF COMBINED PHRASAL TRANSFER

The English sentence for translation is: *What kind of dictionary will Teacher Liu buy?* and the student translated the sentence as:

老师 刘 要 买 哪 词典 ?

which contains two phrasal transfer errors (*Teacher Liu* and *which dictionary*). The example selector has selected one example for each of the phrasal transfer errors and explained to the student the causes of the errors.

Strategy: Assistance

You have produced a Chinese sentence, but it is not a correct translation of the English sentence. The sentence can be translated in the following ways:

约翰 明天 要 买 一 本 杂志 or

明 天 约 翰 要 买 一 本 杂 志 .

```
Please try again!
```

COMMENTS: ASSISTANCE

The English sentence for translation is: *John will buy a magazine tomorrow.* However, the student has entered a Chinese sentence which means *I will go to China this week.* This type of error was rare among students.

```
Strategy: Approval
I am pleased to tell you that your translation is correct. Well done!
```

COMMENTS: APPROVAL

The student has translated a sentence correctly.

In this chapter, the tasks carried out by the Tutor Model have been addressed. The Tutor Model is equipped with a considerable number of tutorial strategies and is able to deliver appropriate help to the student based on the information provided by the Student Model and the Diagnoser.

Chapter 8

The Interface Module

Whereas the Tutor Model decides the sequence of the tutoring and the content of the feedback given to the student, the Interface Module takes care of their final form of the communication. More generally, this model processes the flow of communication in and out [Wenger 1987a]. It takes care of the interaction between the system and the student, i.e. not only understanding the internal representation of the system, but also communicating with the student in a language understandable to him/her.

An important issue that needs to be addressed in this chapter is how interaction takes place. A system can interact with the user through either canned texts or texts automatically generated by a generator. The former is rigid because the text is pre-stored; while the latter is more sophisticated in the sense that an appropriate text can be generated by a generator using concepts provided to the system. The former approach is used in this research because it is a relatively easy way to interact. It is beyond the scope of this Ph.D to generate feedback automatically to the student as such generation is a new field in AI.

The practical importance of the Interface Module is that it handles the system's interaction with users, and such qualities as ease of use, and ease of understanding the feedback and commands provided by the system, can be crucial to the student's

acceptance of the system. The Chinese Tutor has been built so that students should be able to use it with ease, i.e. no training should be needed for students to use the system. Moreover, the response [see *Section 10.3*] from potential users indicates that the Chinese Tutor is fairly easy to use and the feedback provided by the system is helpful.

In this chapter, we will first list the tasks undertaken by the Interface Module and then move on to a brief introduction to the CXTERM program (a Chinese terminal emulator), used by the Chinese Tutor. The help system of the Chinese Tutor will also be discussed. At the end of this chapter, tutorial sessions run by two of the students who used the Chinese Tutor will be presented.

8.1 Tasks Undertaken by the Interface Module

The Interface Module interacts between the system's internal representation and an *interface language* which can be understood by the student. The following main tasks are carried out by the Interface Module of the Chinese Tutor [see *Figure 8.1*]:

- The Interface Module collects the **name** of the student and starts keeping a record of his/her learning history, if the student is using the system for the first time. If the student has used the system before, it will load the record of his/her previous learning history.
- It asks the student to choose a topic for tutorial from the **lesson selection menu**; receives the choice (i.e. **lesson number**) from the student; and outputs a **translation exercise** from the lesson specified to the student for translation.
- The Interface Module collects the **student's input** and provides him/her with feedback (i.e. **normal/additional strategy**) in a format understandable by the student.

- It then outputs the **next task** for the student to do.

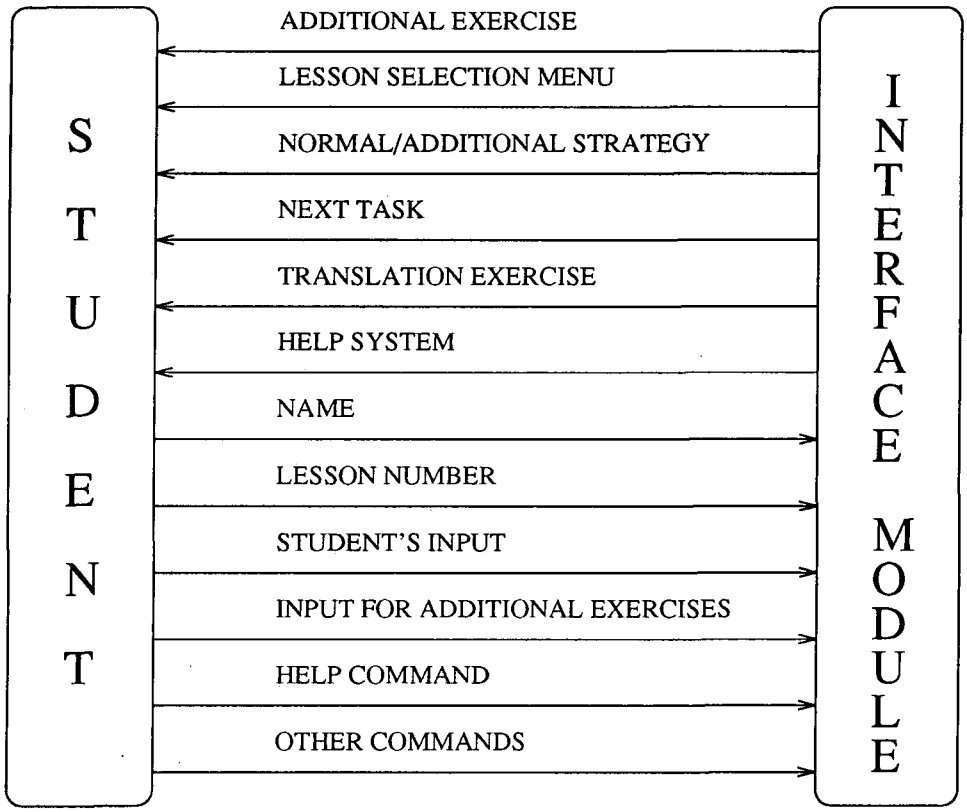

Figure 8.1: Interacting with the User

- If the Tutor Model decides that an additional tutorial is required by the student, the Interface Module will give him/her a series of additional exercises. It receives the student's **input for additional exercises** and outputs the **additional strategy** selected by the Tutor Model.

- At any level in the tutorial session, the student will be presented with the help system when he/she keys in the **help command**. The student can also quit (**other commands**) the system whenever he/she likes.

8.2 CXTERM

The CXTERM program is a Chinese terminal emulator for the X window system which is used by the Chinese Tutor for allowing the student to input Chinese characters. Chinese is not written alphabetically, but in symbols which are known as characters, and a character usually corresponds to a single morpheme. CXTERM was designed by Yongguang Zhang (from Purdue University) and Manchi Pong (from the Hong Kong University of Science and Technology) in 1988 and has since undergone some modifications. It has two modes: Chinese mode and Ascii mode. When it is in Chinese mode, it can convert pinyin into Chinese characters. Pinyin is a system for transcribing the sounds of Chinese in Roman script. When it is in Ascii mode, the CXTERM program accepts all the standard X terminal commands.

CXTERM adds a special display area to the bottom of the window. The Chinese input area is about 2 lines high and is the same width as the text window. To enter a Chinese character, a valid Chinese syllable in pinyin together with its tone is typed into the input area, then it is converted into the Chinese character using an input mapping method. When the same input string can be translated into more than one Chinese character, a selection list of valid Chinese characters is displayed in the input area. A selection key will bring the required character to the screen. The following is a list of advantages of using CXTERM:

1. Rather than designing a Chinese window for ourselves, we can use a pre-existing one.

2. It makes the tutorial sessions more interesting when the student can enter Chinese characters rather than pinyin.

3. It is good practice for the student to choose the appropriate character when CXTERM displays a selection list of valid Chinese characters (i.e. when the student's input string matches more than one character). For instance, for the pinyin *zuo4*, four characters will be displayed on the screen: 1. 做 2. 坐 3. 座 4. 作. If the student needs the character which means *sit*, he/she just

types in the number 2 (in this case) to bring the character 坐 to the screen.

8.3 Help System

The help system of the Chinese Tutor is menu-driven, and is a separate sub-system that can be accessed from the Chinese Tutor. It consists of two parts: the first part deals with how the help system is used; and the second part focuses on the use of the Chinese Tutor.

8.3.1 Use of the Help System

To access the help system from the Chinese Tutor, the student needs to type **h** at any stage of the tutorial session. If a section in the help system is more than one page long, the student should press the space bar, when he/she has finished reading a page, in order to see the next page (or press return to see only one more line). To return to the main menu from a sub-menu, the return key should be pressed instead of a selection number. The following commands are available in the help system:

`q` quit the manual

`<return>` exit one level of menu structure (i.e. if at foot of section, return to menu; if at submenu, return to main menu; if at main menu, quit the manual)

`<number>` display section from current contents page

. (dot) same again, i.e. redisplay last requested section

`+` display next section in numerical order

`-` display previous section

8.3.2 Use of the Chinese Tutor

The following information on the use of the Chinese Tutor is provided by the help system: a general introduction to the Chinese Tutor (such as issues in relation to the tutorial topic in each lesson, tutorial emphasis, the main components of the tool, how it works etc. which have been addressed in the previous chapters); and how to enter input from the Chinese window. In this section, we will concentrate on the latter.

Use of the Chinese Window

The Chinese window contains a special area at the bottom, which is used to display and convert pinyin into Chinese characters. To key in a Chinese character, a valid Chinese input string is typed into the input area, then it is converted into the Chinese character.

Shift <*F1*> is used to switch the Chinese character mode to Ascii mode. *Shift* <*F3*> switches Ascii mode to the Chinese character mode.

Entering a Chinese Word

The user of the Chinese Tutor is expected to enter his/her input word by word with spaces between each word. Chinese is normally written character by character with a space in between. The reason that the student is asked to enter word by word is that it obviates the need for morphological studies on the Chinese language. It would be extremely complicated to define the boundaries of words by a computer.

A word can be either monosyllabic or polysyllabic. A monosyllabic word is formed by one character and includes the following:

- a substantive which contains a complete meaning such as 他 (*he*), 谁 (*who*);

- a word which does not contain any meaning such as prepositions, conjunctions, particles (e.g. 的 , 了).

A polysyllabic word is a word which is formed of more than one character. For instance, the word "library" in Chinese, contains three characters 图 书 馆 , so when the student enters this word, he/she needs to key in the pinyin for the first character, then the second and finally the third, with no spaces between the characters.

Entering a Chinese Sentence

Please refer to *Entering a Chinese Word.* The translated sentence should be entered word by word with spaces between each word, e.g.

我 今天 下午 去 图书馆 .

8.4 Tutorial Sessions Run by Potential Users

The following are two examples of tutorial sessions run by students who have used the Chinese Tutor. The first tutorial is a normal tutorial session which concentrated on the use of point of time in Chinese; the second contained a normal and additional tutorial session and focused on prepositional phrases formed with the coverb 在 as an adverbial of place.

8.4.1 Tutorial Session I

Miranda go

您 好 ! Welcome to Chinese Tutor! For further information, please type h.

Please enter your name: **Student X**

Please enter lesson number and hit Return(6, 8, 10, 13, 14a, 14b, 16, 17a, 17b, 21, 24, 25a, 25b, 25c, 28a, 28b, 30a, 30b, 34, 37, 40a, 40b, 44, 54): **17b**

Task 1: WE HAVE BREAKFAST AT EIGHT.

Please enter answer and hit return: 我 们 吃 早 饭 八 点 .

I'm sorry to say that you haven't translated the sentence correctly. You may translate the sentence in the following ways:

(1) 我 们 八 点 吃 早 饭 .

(2) 八 点 钟 我 们 吃 早 饭 .

The problem with your translation is that you have translated the sentence according to the English word order. Please compare your translation with the standard translations in order to find out the differences between the structures and try again!

Task 2: THEY(MALE) HAVE LUNCH AT ONE.

Please enter answer and hit return: 他 们 吃 午 饭 一 点 .

Your translation is not correct. The sentence can be translated in the following ways:

(1) 他 们 一 点 吃 午 饭 .

(2) 一 点 钟 他 们 吃 午 饭 .

Here is an example to help you: 六 点 起 床

Time words or time phrases in Chinese normally precede predicates. They can also be put at the beginning of a sentence. They cannot, however, be put at the end of

a sentence, as they can in English.

Task 3: JOHN HAS SUPPER AT EIGHT.

Please enter answer and hit return: 约 翰 八 点 吃 晚 饭 .

I'm pleased to tell you that your translation is correct. Well done!

Task 4: THEY(FEMALE) STUDY CHINESE AT NINE.

Please enter answer and hit return: 她 们 九 点 学 汉 语 .

You have translated the sentence correctly again! We think that you are very familiar with the tutorial topic of this lesson and you may move on to another lesson.

Please enter lesson number and hit Return(6, 8, 10, 13, 14a, 14b, 16, 17a, 17b, 21, 24, 25a, 25b, 25c, 28a, 28b, 30a, 30b, 34, 37, 40a, 40b, 44, 54):

Comments:

1. *Student X* started the Chinese Tutor by typing *go*. The Chinese Tutor output a *welcoming message* together with the *command* for the help system in case the student would like to know more about the system. The student was then asked to enter his/her *name*.

2. After the student had entered the name, the Chinese Tutor presented him/her with a *lesson selection menu* containing a whole list of lessons provided by the Chinese Tutor. The student could select one of the lessons.

3. Student X chose *Lesson 17b* for the tutorial.

4. The Chinese Tutor asked the student to translate *Task 1* (an English sentence) into Chinese from the lesson specified by the student.

5. The student typed in the *answer* for Task 1, the system evaluated it and provided the student with *feedback*. When Student X made a transfer error for the first time, the Chinese Tutor gave him/her some hints on why the translation was not correct.

6. The Chinese Tutor then asked the student to try again by assigning *Task 2* to him/her from the same lesson. When a transfer error was made for the second time, the Chinese Tutor selected a different tutorial strategy. It commented on the student's performance, provided him/her with standard translation(s), chose an appropriate example, and explained how a correct translation can be formed and why his/her translation was not correct.

7. The system gave the student *Task 3* and the student did it correctly this time. Once the student has fulfilled the task twice, he/she is allowed to move on to another lesson.

8.4.2 Tutorial Session II

Miranda **go**

您 好 ! Welcome to Chinese Tutor! For further information, please type h.

Please enter your name: **Student Y**

Please enter lesson number and hit Return(6, 8, 10, 13, 14a, 14b, 16, 17a, 17b, 21, 24, 25a, 25b, 25c, 28a, 28b, 30a, 30b, 34, 37, 40a, 40b, 44, 54): **14a**

Task 1: HE STUDIES ECONOMICS IN JAPAN.

Please enter answer and hit return: 他 学习 经济 在 日本 .

I'm sorry to say that your translation is not correct. The sentence can be translated

in the following ways:

(1) 他 在 日 本 学 经 济 .

(2) 他 在 日 本 学 习 经 济 .

The problem with your translation is that you have translated the sentence by referring to the English sentence structure, which is not correct in Chinese. Please compare your translation with the standard translations in order to find out the differences between the structures and try again!

Task 2: WE WILL LISTEN TO THE MUSIC IN THE COLLEGE.

Please enter answer and hit return: 我 们 听 音 乐 在 学 院 .

Your translation is still not right. You may translate the sentence in the following ways:

(1) 我 们 要 在 学 院 听 音 乐 .

(2) 我 们 在 学 院 听 音 乐 .

Here is an example to help you: 在 外 语 系 前 边 等 汽 车

The prepositional phrases formed with the coverb "在 " in Chinese normally come before the predicate. This is different from the word order in English in which prepositional phrases follow predicates. Please try again!

Task 3: JOHN STUDIES CHINESE IN BRITAIN.

Please enter answer and hit return: 约 学 中 文 在 英 国 .

There is more than one thing wrong with your translation. For the moment, we'll concentrate on the major problem. This sentence can be translated in the following ways:

(1) 约 翰 在 英 国 学 习 中 文 .

(2) 约 翰 在 英 国 学 汉 语 .

You have translated the sentence according to the English sentence structure again. Please bear in mind the previous explanations, and try some pair choice exercises and sentences built up from constituents.

Task 4 (Please select the correct sentence by entering a number):

1. 我 爸 爸 在 北 京 大 学 工 作 .

2. 我 爸 爸 工 作 在 北 京 大 学 .

Please enter answer and hit return: **1**

You have chosen the correct sentence, well done!

Task 5 (Please select the correct sentence by entering a number):

1. 他 等 车 在 历 史 系 前 边 儿 .

2. 他 在 历 史 系 前 边 儿 等 车 .

Please enter answer and hit return: **2**

You have made the right choice, well done!

Task 6 (Please put the constituents in the right order by entering numbers):

pronoun	verb	coverb	noun
我	工 作	在	大 学
1	2	3	4

Please enter answer and hit return: **13 4 2**

You have constructed a correct Chinese sentence.

Task 7 (Please put the constituents in the right order by entering numbers):

pronoun	verb	proper noun	noun	coverb
他	学	中国	汉语	在
1	2	3	4	5

Please enter answer and hit return: **1 5 3 2 4**

That's a well-constructed sentence! Here is another sentence for you to translate:

Task 8: MY ELDER SISTER STUDIES HISTORY IN SPAIN.

Please enter answer and hit return: 我 姐姐 在 西班牙 学 历史 .

Well done! You have translated the sentence correctly.

Task 9: HE WILL BUY A RADIO IN THE SHOP.

Please enter answer and hit return: **q**

再见！谢谢 您！

Comments:

1. *Student Y* has selected *Lesson 14a* for the tutorial.
2. The student was asked to translate an English sentence (*Task 1*) into Chinese from the lesson specified.
3. The student's translation in Task 1 contained a structural transfer error, therefore the Chinese Tutor gave some hints to the student on the possible causes of the problem in the translation.

4. The Chinese Tutor then assigned *Task 2* from the same lesson for the student to do. When a critical transfer error was made for the second time, the student was provided with a detailed and clear explanation as to the cause of the error. An appropriate example was also given to help the student.

5. The system then assigned the student *Task 3* and he/she gave an incorrect answer for the third time. Once the student had made consistent critical transfer errors, the Chinese Tutor changed its tutorial strategy by asking the student to engage in additional tutorials, in order to help the student grasp the basic structure of this particular rule.

6. The Chinese Tutor started the additional tutorial by providing the student with the first pair choice exercise (*Task 4*) on the same grammatical point, which was selected by the additional exercise selector. The student fulfilled the task.

7. In order to make sure that the student could tell the correct sentence from the incorrect one, the student was given another pair of sentences, *Task 5.*

8. Student Y chose the right sentence again. The system decided to provide some slightly more complicated exercises which required building up sentences from constituents, *Tasks 6* and *7.* (The system is flexible in the sense that it allows the student to enter the answers with extra spaces or no space between the numbers.)

9. After the student demonstrated his/her ability in doing the additional exercises, he/she was asked to do another translation exercise (*Task 8*) from the same lesson, and he/she did it correctly this time. When the student quit the system, the Chinese Tutor output a message in Chinese to say goodbye and thank the student for using the system.

The above tutorial sessions show that the normal and additional tutorials provided by the Chinese Tutor can be effective in helping students overcome errors of negative transfer.

Chapter 9

General Implementation Issues

One of the most significant decisions which must be made when designing a system is which programming language to use in the implementation of the system. Selecting an appropriate programming language minimises the difficulties in coding a design, reduces the amount of program testing required, and makes the program more readable and hence more easily maintained [Sommerville 1982].

The Chinese Tutor has been written in the programming language Miranda: this has led to the code being easy to understand and hence easy to maintain. Miranda is a pure functional language with non-strict semantics and a polymorphic type checking system [Turner 1985]. The scale of the implementation of the Chinese Tutor is large, with approximately 2000 lines of source code (not including comments) in Miranda, distributed across to five models. The Chinese Tutor has approximately 3500 translation exercises, standard translations, additional exercises, standards for additional exercises, examples and explanations. It is equipped with 17 normal tutorial strategies and 2 additional tutorial strategies.

In this chapter, we will first briefly introduce some of the important features of Miranda and discuss why Miranda has been chosen as the implementation language for the Chinese Tutor, and then move on to a list of attributes possessed by the Chinese Tutor.

9.1 Important Features of Functional Programming

Some of the important features of functional programming languages which make them particularly suitable for developing large-scale prototypes will be introduced in this section. We shall focus in particular, on the reasons why these features make the program easier to comprehend and hence simplify the maintenance task. These features are referential transparency, currying, abstract types, higher-order functions, lazy evaluation and prototyping.

9.1.1 Referential Transparency

Pure functional programming languages have the property of referential transparency, a property also possessed by mathematical notation. This allows a functional language to prohibit side-effects such as assignments and *goto*s, which often make it very difficult to reason properly about the code. This also allows the value of an expression to rely solely on the values of its sub-expressions and there are no hidden effects affecting its value. Thus sub-expressions may be replaced directly by another expression with the same value. Moreover, different occurrences of the same name always have the same value, unlike in imperative languages, where a variable may be assigned several different values within an expression. The properties of referential transparency can contribute to the ease of understanding of a program written in a functional language [Hazan 1993].

9.1.2 Currying

Currying is a device for replacing structured arguments by a sequence of simple ones [Bird 1988a]. For instance, a function **f** applied to two arguments **x** and **y** is represented in Miranda as **f x y**, meaning that the result of applying **f** to **x** is a

function which is then applied to **y**. If we define the function **add** such that

```
add x y = x + y
```

then **add 2 3** is interpreted as (**add** 2) 3, where (**add** 2) is a function which takes a single argument and adds the value 2 to it. If the function were to be written in an uncurried form, such as

```
add (x,y) = x + y
```

the function to **add 2** to a number would have to be written as a separate new function. This feature makes it possible for functions to be greatly simplified merely by leaving out arguments when they are not necessary, thus aiding readability and abstraction [Hazan 1993].

9.1.3 Abstract Types

An abstract type is a section of code which appears to the application programmer as independent of any particular representation. The only way to process values of the type is to use functions specifically provided to access the type. The representation of an abstract type can thus be altered without any effect on programs which use it, because the type is completely determined by the functions and their behaviour [Holyer 1991a].

An abstract type is defined by naming its operations, not by naming its values. How values are represented is therefore less important than what operations are provided for manipulating them. This is just the reverse with so-called 'concrete' types, in which the values are prescribed, but the operations are not. The function of each operation in an abstract type is described either by an *algebraic specification*, stating the relationships between the operations as a set of algebraic laws, or *models*, describing each operation in terms of the most abstract representation possible [Bird 1988b].

For the implementation of an abstract type, the programmer needs to provide

a representation of its values, define the operations of the type in terms of this representation and show that the implemented operations satisfy the prescribed relationships. Apart from these obligations, the programmer is free to choose between different representations on the grounds of efficiency or simplicity [Bird 1988b].

9.1.4 Higher-Order Functions

A function which takes a function as an argument, or delivers one as a result, is called a higher-order function [Bird 1988c]. This allows functions such as **map** to be written, which applies a given function to each member of a list. Thus instead of defining the recursive function **squares** to calculate the **square** of each member of a list of numbers, one may simply write **map square**, where square returns the **square** of a single number.

The use of higher-order functions is an important feature of programming style in functional languages, and often lends itself to very concise forms of expressions [Turner 1987]. The use of higher-order functions and lazy evaluations [see *Section 9.1.5*] allows new levels of modularity to be attained; this also enables programs to be more easily read and understood [Hughes 1989].

9.1.5 Lazy Evaluation

A function calling mechanism is used in which unevaluated expressions may be passed as arguments to any function only once, and it is regarded as the function's responsibility to evaluate those expressions as and when their values are needed, this is called lazy evaluation [Holyer 1991b]. Lazy evaluation allows programs to manipulate expressions, such as lengthy or infinite lists, whose evaluation would otherwise be needlessly time-consuming or indeed fail to terminate at all. Lazy evaluation also allows the programmer to separate different aspects of his/her program that would otherwise need to be implemented as one block. For instance, a problem may be divided into: a set of functions that generate candidate solutions;

and a set of functions to decide which of the generated solutions should be used. In an imperative language, all the solutions would be generated before the program could proceed to the set of functions that used these solutions. If only the first solution were used, the cost of building the other solutions would have been wasted. In a functional language, only the solutions that were used would be built.

9.1.6 Prototyping

Functional languages are highly suited for rapid prototyping [Holyer 1991b]. They provide a very high-level programming environment and a program written in a functional language tends to be much shorter than the equivalent program written in an imperative language [Turner 1982]. A prototype can therefore be written more quickly in a functional language than an imperative language. For this reason, and also because of the properties possessed by functional languages, the whole software development process is shorter as less time needs to be spent in the debugging and maintenance of the program [Holyer 1991b].

9.2 Attributes Possessed by the Chinese Tutor

In *Section 1.2* on the *Criteria for Success of this Research*, a list of important attributes that should be followed by the design of a general solution to a particular problem have been addressed. In this section, we will examine the implementation of the Chinese Tutor on those grounds.

- **Scale**: The dictionary of the Chinese Tutor comprises over 1,000 Chinese words, which cover the whole vocabulary in the two textbooks the students use in their first year study of Chinese grammar. The Chinese Tutor has approximately 250 grammatical rules of Chinese and English, designed to deal with the errors identified in the test papers.

- **Integration**: There are five main components in the Chinese Tutor: the Expert Model, the Student Model, the Diagnoser, the Tutor Model and the Interface Module and they have been implemented in that order, so that the implementation of one component will assist in the implementation of other components. For instance, the reason for implementing the Expert Model first is that it serves as the core for the whole system.

- **Flexibility**: It is possible to change any part of the Chinese Tutor with little disruption to other parts of the system. For instance, if a language tutoring system needs to be developed for tackling negative transfer when English-speaking students learn Japanese, most of the Chinese Tutor could be used with very few alterations.

- **Feasibility**: The Chinese Tutor runs under X windows on a SPARC station. The response of the Chinese Tutor is quick [see *Appendix E*]. It is capable of providing feedback to the student within a few seconds. It is also capable of responding to the student's input with a combination of transfer errors within acceptable limits.

- **Robustness**: The Chinese Tutor is robust in the following two aspects. *First*, the Chinese Tutor can automatically locate transfer errors, both simple and complicated ones, using the rules in the Mixed Grammar. The methods employed by other existing tools in handling mother tongue influence are much more restricted than the Chinese Tutor, since they need to specify some of the (complicated) transfer errors. *Second*, the Chinese Tutor does not crash when the input from the student deviates from what is expected. For instance, if the student types in English when Chinese characters were expected, the system will report to the student that the input is invalid and ask him/her to try again.

- **Maintainability**: The Chinese Tutor has been written in a pure functional language: this has led to the code being easy to understand and hence maintainable. The extensive use of abstract data types at all levels also contributes to the ease of maintenance and comprehension of the source code.

- **Usability**:

  The feedback from the potential users was very encouraging. The students at Durham, who have used the Chinese Tutor, said it could be very helpful in guiding them over the difficulties in their study of Chinese. The students were happy with the Chinese Tutor and they did not suggest any changes [see *Appendix E*].

Chapter 10

Evaluation

It is of great importance for the designers of language tutoring systems to evaluate their tools/systems in order to ensure that their requirements have been met. Few ITSs have been subjected to a formal evaluation [Shute 1993]. In *Section 1.2.3*, we have discussed a long-term evaluation of a tutoring system, which would be to test it, on a set of people taken from a large population of potential users, over a long period of time (a year, for instance). The students would be divided into two equal groups. One group interacts with the system, while the other goes through the exercises provided by the text books on their own. At the end of the evaluation, a comparative study would be carried out to see which group progressed more quickly. The Chinese Tutor does not carry out the evaluation. This is simply because this kind of evaluation is beyond a Ph.D thesis, as it would require an enormous amount of effort (setting up the system in the Department of East Asian Studies, making arrangements with the Department etc.) and time to make it happen.

A preliminary short-term evaluation has been undertaken by this research on the Chinese Tutor. The Chinese Tutor has undergone system (i.e. the program) testing; acceptance (i.e. end-user) testing; and expert testing (i.e. demonstrating the Chinese Tutor to experts on Chinese).

In system testing, the Chinese Tutor demonstrated that it can cope with the

specially designed test cases. The Chinese Tutor did not crash, was robust and maintainable. The techniques of defect testing have been used in the system testing. These techniques include both black-box or functional testing, and white-box, glass-box, or structural testing. The component is a 'black box' whose behaviour can only be determined by examining its inputs and the related outputs. A complementary approach to testing is sometimes called 'white-box' testing. This term contrasts with 'black-box' testing in that the programmer can analyse the code and use knowledge about it and the structure of a component to derive the test data [Sommerville 1992c].

In the acceptance testing, the Chinese Tutor was tested by first-year students from the Department of East Asian Studies at the University of Durham. A questionnaire was issued and the students thought that the Chinese Tutor could be very useful in helping them remove transfer errors.

In the expert testing, the Chinese Tutor was demonstrated to the grammar lecturer of the first-year students, in the Department of East Asian Studies at the University of Durham. The grammar lecturer believed that their first-year students should be able to benefit from the Chinese Tutor.

The only existing tool in language tutoring which has *some form* of testing is **XTRA-TE**. By *some form* of testing, we mean that the designers of XTRA-TE claimed that informal testing on end-users was carried out. However, its designers did not address how the system testing of XTRA-TE was undertaken.

In this chapter, we will first discuss issues in connection with evaluation: the process of testing; the techniques used in testing the Chinese Tutor; the acceptance testing; and the expert testing. We will then compare the Chinese Tutor with other existing tools, in language tutoring, by referring back to the list of important practical and technical features which were discussed in *Section 3.2.1* on the *Capabilities and Limitations of Existing Language Tools.*

10.1 Process of Testing

The Chinese Tutor is a large-scale prototype system which was built out of subsystems, which were, in turn, built out of modules, which were composed of functions. The testing process of the Chinese Tutor has been carried out, according to the testing process suggested by Sommerville [Sommerville 1992a], in stages where testing has been undertaken incrementally in conjunction with system implementation. The testing of the Chinese Tutor consisted of five stages.

10.1.1 Unit Testing

Testing of individual components is used to ensure that they operate correctly. Unit testing handles each individual component as a stand-alone entity which does not require other components during the testing process. The individual functions in the Chinese Tutor have been tested. The following is an example of a function in the Mixed Grammar of Chinese and English.

```
> numeric_measureWord_ph = (perm "numeric_measureWord_ph ") $n_
>                                  number $t2_ nominal_measureWord
```

The function *numeric_measureWord_ph* is made up of a *number* followed by a *nominal measure word*. A number of test cases in Chinese formed with a *number* and a *nominal measure word* were used to test whether the function worked correctly.

10.1.2 Module Testing

A module is a collection of dependent components which can be tested mainly on its own. The modules in the Chinese Tutor have been tested individually in order to make sure that they work properly. One of the modules in the Chinese Tutor is *CompareTranslation* which compares the student's input string with all

the possible standard translations for a particular sentence, and returns the result of the comparison. The comparison result indicates one of the following levels of familiarity: excellent, good, average, below average and poor. The functions in this module have been tested together to ensure that the tasks are carried out as required.

10.1.3 Sub-system Testing

This stage involves testing collections of modules which have been integrated into sub-systems. The main goal of sub-system testing is to check if the modules combine together correctly to achieve a product that satisfies its specification. Particular care have been paid to testing the interfaces. The following are the sub-systems in the Chinese Tutor: the Mixed Grammar of Chinese and English and the parser; the Student Model and the Diagnoser; the Tutor Model; the Interface Module; and the help system. The sub-system testing for the Chinese Tutor concentrated not only on diagnosing errors in each individual sub-system, but also on the detection of interface errors by exercising these interfaces.

10.1.4 System Testing

The sub-systems are integrated to make up the entire system. System testing focuses on discovering errors which normally result from unanticipated interactions between sub-systems and components. For instance, there were some problems caused by the integration of the help system into the rest of the system. The help system needed to be accessible by the student at any stage of the tutoring.

10.1.5 Acceptance Testing

This is the final stage in the testing process. Acceptance testing involves testing the system with data supplied by the potential users, rather than simulated data developed as part of the testing process. A detailed discussion on how the Chinese Tutor has been tested on end-users will be given in *Section 10.3.*

10.2 Testing Techniques Used in this Research

The testing techniques adopted in this research are incremental testing (the system is built in increments for testing); defect testing (tests are designed to reveal defects in the system); and regression testing (testing of changes to the system). There are three factors which made testing of the Chinese Tutor easy. *First*, the Chinese Tutor has been written in the programming language Miranda, which led to the code being easy to understand [Hazan 1993]. *Second*, the use of a natural language parser has saved us a great deal of time in debugging since the major bugs have been corrected before. *Third*, the modular design makes it possible for a module of the Chinese Tutor to be modified without disrupting the rest of the program.

10.2.1 Incremental Testing

Sommerville [Sommerville 1992b] suggests that rather than take all modules, and combining them to start testing, the system should be built in increments. Each section should be tested before the next section is added to the system.

Figure 10.1 shows the testing sequence of the main models of the Chinese Tutor. The grammatical rules in the Mixed Grammar and the parser were tested first. In *Test Sequence 2*, the Student Model and Diagnoser was added to the system, and so on. Once the last section, the Interface Module (in this case), was added to the system, the Chinese Tutor was tested as a whole.

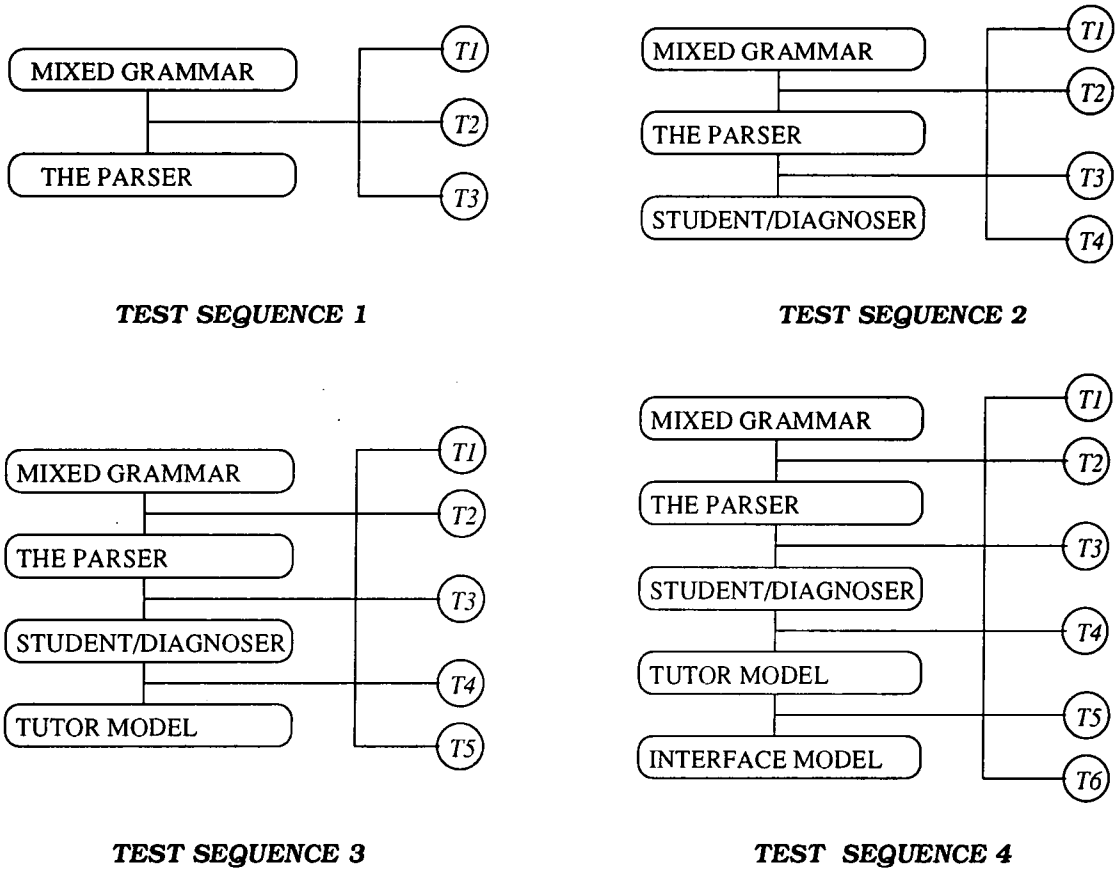

Figure 10.1: Incremental Testing

10.2.2 Defect Testing

The testing of a program has two objectives [Sommerville 1992c]: *first*, it is intended to show that the system meets its specification; *second*, it is intended to exercise the system in such a way that defects are exposed. The techniques that have been used in this research for defect testing include black-box testing with equivalence partitioning, and white-box testing. Equivalence partitioning is a technique for determining which classes of input data have common properties. The program specification and the experience of the programmer (to predict which classes of input value are likely to detect errors) can be used for identifying the equivalence partitions [Sommerville 1992c].

The technique of equivalence partitioning has been applied in formulating test

cases with both correct and incorrect input. These instances have been selected from the examples in the students' test papers and the translation exercises which the Chinese Tutor provides for the students. However, a disadvantage of using equivalence partitioning is that, even when a program operates successfully for individual test inputs, combinations of these inputs may detect program errors. Equivalence partitioning provides no help in selecting these combinations [Sommerville 1992c]. So, in order to select combinations which test the program more thoroughly, another approach, white-box testing is applied. This approach focuses on testing the nodes of the conditions such as recursion, conditional expressions etc.

10.2.3 Regression Testing

There are two aspects [Schach 1990c] in the testing of changes to a system. The first aspect is to ensure that the changes have been correctly implemented, i.e. the coding which was required is correct. The second aspect is to make sure that, in the course of making the required changes, no other accidental changes have been introduced which affect the performance of other modules. The system must be tested against previous test cases, once the desired changes have been implemented. This procedure is called *regression testing.* When some changes were made to the Chinese Tutor, the previous test cases were also carried out in order to make sure that they still worked properly.

10.3 Feedback from the Potential Users

An evaluation [see *Appendices D* and *E*] of the Chinese Tutor has been carried out by potential users, i.e. first-year students in the Department of East Asian Studies at the University of Durham. The students were asked to fill in a questionnaire after they used or saw a demonstration of the Chinese Tutor. Ten students replied and the overall feedback from the students was positive. The Chinese Tutor was

used by four students for several hours. Ten questions were asked, and for the first seven questions, numbers 1 to 5 were used for indicating levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = no preference, 4 = agree, and 5 = strongly agree. Questions eight and nine were yes-no questions. The following are the results of the evaluation.

Question 1 asked whether the student thought that it would be useful to have a Chinese tutoring system helping him/her to overcome common errors in his/her first-year study of Chinese. The average result from the ten students was **5**.

Question 2 was to see whether the student thought that interacting with a Chinese tutoring system could help him/her more efficiently than doing exercises on his/her own. The average result was **4.8**.

Question 3 asked the student if he/she thought that the translation exercises provided by the Chinese Tutor were useful, and the average result was **4.6**.

Question 4 was used to find out whether the student thought that the additional exercises were helpful, and the result was **4.2**.

Question 5 was used to check whether the response of the Chinese Tutor was fast enough, and the result for this question was **4.1**.

Question 6 was on whether the student thought that the feedback given by the Chinese Tutor was helpful and the result was **4.4**.

Question 7 was used to find out whether the Chinese Tutor was easy to use and the result was **3.7**. However, for students who had actually used the Chinese Tutor, the average result was **4.5**.

Question 8 asked the student whether he/she found the Chinese Tutor helpful in overcoming errors of negative transfer. A positive answer was given by all the students.

Question 9 was used to find out whether the student had come across any manual exercises which were specially designed for helping students to overcome

mother tongue influence. A negative answer was given by all the students.

Question 10 was used to check what other features the student would like to see in a tutoring system. Two out of ten students answered this question. One student put: "I can't think of anything else I would like to add, it seems excellent". The other student put: "At the moment, I can't give any other features which may be useful, but once I have studied more, I may be able to help". We assume that the other eight students were also happy with the Chinese Tutor since they did not suggest any changes.

The above results of the evaluation indicate that, the overall reaction on the Chinese Tutor from first-year students was good. The students thought that the Chinese Tutor could be helpful in eradicating errors of negative transfer.

10.4 Feedback from the Expert on Chinese

The Chinese Tutor has been demonstrated to first-year grammar lecturer in the Department of East Asian Studies at Durham. The feedback from the lecturer was positive. Please refer to *Appendix F* for the survey questions.

The lecturer *strongly agreed* that the translation exercises provided by the Chinese Tutor were well designed; the additional exercises were effective in assisting students whose learning of Chinese grammar has been greatly affected by the grammar of English; and the feedback provided by the Chinese Tutor was appropriate.

The lecturer thought that the Chinese Tutor could detect types of error accurately and the students could overcome mother tongue influence more quickly by using this kind of system than by merely doing exercises on their own. The expert also thought that there was a possibility that her department could use a language tutoring system such as the Chinese Tutor in tutorials, in particular on an individual basis.

10.5 The Chinese Tutor and Existing Tools

In *Section 3.2.1*, issues relating to the capabilities and limitations of existing language tools were addressed, without being compared with the Chinese Tutor. We think the comparison between the Chinese Tutor and other existing tools should be carried out in this chapter, after the Chinese Tutor has been properly introduced. One may find it helpful to refer back to the tables in *Section 3.2.3*, a summary of the main features of each tool. A major drawback shared by all the existing tools is that, in language tutoring, there is still no existing tool which has been designed for tackling a practical problem in the field of language learning, and is equipped with all the important technical features for the development of an intelligent language tutoring system.

In *Section 3.2.1*, the existing tools have been examined from two aspects: the practical aspect and the technical aspect. The Chinese Tutor will be compared on the same grounds.

10.5.1 Practical Aspect

The design of the Chinese Tutor has been based on instructional needs in language learning of Chinese, which were discovered by the empirical studies undertaken as part of this research. Empirical studies can be used as an important means of finding out what kind of help is required by students. These studies make it possible for an ILTS to have a good knowledge of the difficulties encountered by students in second language learning, and thus provide tutorials which can be tailored to the needs of each student. None of the existing tools has been designed on the basis of a practical approach such as empirical studies. Therefore, the Chinese Tutor is the only existing language tutoring system which has a firm foundation on which it was built.

10.5.2 Technical Aspect

The list of features that were considered under the technical aspect is: *Grammatical Coverage*, *Range of Errors Diagnosed*, *Grammar Diagnosis*, *Current State of Learning*, *Updating of Student Model*, *Tutorial Plans* and *Tutorial Strategies.*

Grammatical Coverage

There are approximately 250 grammatical rules in the Mixed Grammar and compared with other existing tools, it is of *reasonable* (i.e. *medium*) size. The only existing tool which has a larger grammatical coverage is **XTRA-TE**. According to the designers, XTRA-TE contains approximately 500 grammar rules and is *very large.* Terms such as *limited*, *medium* and *large* have been defined in *Section 3.2.1.*

Range of Errors Diagnosed

The Chinese Tutor can detect the following types of error.

- Single Transfer Error:
  - a lexical transfer error
  - a phrasal transfer error
  - a syntactic transfer error
  - a global transfer error
- Single Non-Transfer Error:
  - a lexical error
  - a syntactic error
- Combinations of Errors:
  - a combination of transfer errors
  - a combination of non-transfer errors
  - a combination of transfer error(s) and non-transfer error(s)

The range of errors detected by the Chinese Tutor is large compared with other existing tools. The designers of **XTRA-TE** and **Schwind's ILTS** claim that their systems can handle some semantic errors. There are two kinds of semantic error detected by **XTRA-TE**: adjective-noun match and noun-verb match. The only type of semantic error diagnosed by **Schwind's ILTS** concerns the violation of verbs and their complements. Most of the examples in relation to semantic errors given by the above designers, as shown in *Section 3.2.1*, were transfer errors which could be dealt with by the Chinese Tutor.

Grammar Diagnosis

The grammar diagnosis of the Chinese Tutor is *general* and *robust* as a wide range of errors made by the students (including word order transfer and combinations of transfer errors) can be detected using a general set of rules. The grammar diagnosis of **XTRA-TE** and **Schwind's ILTS** is *quite sophisticated*, however, these two systems are unable to automatically locate complicated transfer errors such as word order transfer and combinations of transfer errors. **Scripsi**'s grammar diagnosis is *sophisticated* compared with other existing tools. However, there are two main drawbacks in Scripsi's approach to the handling of transfer: the duplication of linguistic knowledge in the grammar of the student's native language and its simplistic error detection routine.

Current State of Learning

The Chinese Tutor infers the student's current state of learning from the parsing result generated by the parser. The student's current state of learning contains information on whether he/she has mastered a particular rule; to what extent he/she has fulfilled the task; what types of error have been made; and how often a specific kind of error has been made. This information makes it possible for the Tutor Model to tailor its tutorial strategies.

None of the designers of the existing tools has explained how their systems infer

the student's current state of learning.

Updating of Student Model

The Student Model is updated after each of the student's answers has been analysed by the Diagnoser. The Student Model is updated by changing some of the values (such as how often a particular kind of critical error has been made and how many times a rule has been mastered by a particular student). By updating the Student Model, the Chinese Tutor can have a good knowledge of the overall performance of the student, and thus select an appropriate tutorial strategy for the student.

. None of the existing tools contain this important feature.

Tutorial Plans

The tutorial plans of the Chinese Tutor contain how the ultimate goal of the Chinese Tutor can be achieved; how a tutorial strategy should be selected; how the tutorial strategies can be made flexible; when additional tutorials are needed; and when the student should be allowed to move on to another lesson.

The only existing tool which has some tutorial planning is **XTRA-TE**, the drawbacks of which were discussed in *Section 3.2.1.*

Tutorial Strategies

The choice of a tutorial strategy made by the Chinese Tutor is sophisticated in that it is determined by the kind of help required by the student, which is indicated by the diagnostic results (such as the type of error made), the updated results (such as how often a particular kind of error has appeared), and the results of the evaluation (how serious an error is).

The selection of a tutorial strategy by the Chinese Tutor is more sophisticated

and flexible than that of **XTRA-TE** and **Schwind's ILTS**, the drawbacks of which were addressed in *Sections 3.2.1*, *7.2.2* and *7.2.3*.

10.6 Disadvantages of the System

The Chinese Tutor is by no means a 'perfect' language tutoring tool. As is the case with most language tutoring systems, the Chinese Tutor has its limits on the range of linguistic knowledge it handles. It is the author's belief that the issue is more of time and effort to be invested than of theoretical principles.

The following are the disadvantages:

- the vocabulary in the Chinese dictionary is limited;
- the range of grammatical rules in the Mixed Grammar of Chinese and English is not large;
- the feedback provided by the Chinese Tutor is, to some extent, pre-stored;
- the exercises provided are restricted to translation exercises and additional exercises;
- and the Chinese Tutor does not carry out semantic analysis.

The reason behind the first two drawbacks is that we have strictly modelled the linguistic knowledge of Chinese (vocabulary and grammar) of first-year students in their study of Chinese. And it is for this purpose alone, overcoming transfer errors in first-year students in their study of Chinese, that the Chinese Tutor has been designed. Therefore, though the grammar and the vocabulary is limited, the tool has enough knowledge to perform its required task. This is strengthened by the fact that the system has been designed on the basis of real data taken from empirical studies.

The feedback provided by the Chinese Tutor is relatively rigid in the sense that it is not automatically generated by the system. It is beyond the scope of this Ph.D to generate an appropriate feedback automatically as such generation is a new field in AI.

There are three kinds of exercise provided by the Chinese Tutor: translation exercises, pair choice exercises and sentences built up from constituents. Other kinds of exercise (such as free construction) can also be designed in order to make the tutorial more versatile. In exercises of free construction, the student can be asked to form their own Chinese sentences by using the rule specified by the system.

The Chinese Tutor does not undertake semantic analysis on the student's input. This is caused by the fact that the design of the system has been strictly based on the empirical data which indicates that errors of negative transfer can be used to account for 78% of the errors made by the students.

Chapter 11

Conclusions and Future Research

In this chapter, we will first check if this research has met its criteria for success. We will then discuss some possible research directions, and finally what the Chinese Tutor can offer students and teachers.

This research has been undertaken following the criteria for success which were described in *Section 1.2*. In order to discover what kind of help is required by English-speaking students in their first-year study of Chinese grammar, empirical studies have been carried out as part of this research. The results of the empirical studies indicate that a large proportion of students' errors can be explained by negative transfer. If students can be helped to eliminate these errors using a language tutoring tool, the students' standard of Chinese will be improved, while it could save lecturers the large amount of time devoted to correcting these errors, thus freeing them for more advanced work. A general and robust solution to the treatment of transfer (i.e. the technique of Mixed Grammar) has been devised. A short-term evaluation (system testing, user testing and expert testing) has been used to test if the Chinese Tutor is successful.

The empirical studies have been undertaken in accordance with general principles. The data collection was based on the standard tests given by the Department of East Asian Studies at the University of Durham as a routine to check how well

their first-year students have mastered the grammatical rules that they were taught in a particular week. The period during which the data was collected covered a whole learning curve during which the students finished learning the grammar of the two set textbooks. The data collection was also statistically meaningful because all of the first year native English speakers were modelled.

The solution to the problem of transfer, i.e. the technique of Mixed Grammar, is general. The design of the solution has followed the following principles: *scale*, *integration*, *flexibility*, *feasibility*, *robustness*, *maintainability* and *usability*, which were discussed in *Section 1.2.2* and *9.2*. The size of the Chinese Tutor's dictionary and grammar is reasonably large. The core of the whole system has been implemented first, so that it can assist in the implementation of other components. The Chinese Tutor is flexible because it is possible to change any part of the system with little disruption to other parts of the system. It is feasible and can serve a useful purpose. The system is robust because *first*, it can automatically locate transfer errors using the rules in the Mixed Grammar, and *second* it does not crash when the input from the student deviates from what is expected. The Chinese Tutor has been written in a pure functional language: this has led to the code being easy to understand and hence maintainable. The feedback from the potential users was very positive.

The technique of Mixed Grammar has overcome the current inadequacies in handling the automatic detection of transfer errors. The Mixed Grammar of Chinese and English has been modelled in a way which allows the parser to locate complicated transfer errors not only by examining the error itself, but also by checking its links with other constructs in the input. Moreover, the grammatical rules in the Mixed Grammar of Chinese and English can be used to pinpoint arbitrary transfer errors made by students, using a general set of rules.

The short-term evaluation (i.e. system testing, acceptance testing and expert testing) has been used for testing the Chinese Tutor. In system testing, the Chinese Tutor has coped well with the specially designed test cases and showed all the models in the Chinese Tutor can work effectively together for eradicating transfer

errors. The Chinese Tutor has demonstrated the following abilities. It can

- locate arbitrary transfer errors;
- infer the current state of learning of the student;
- update the Student Model;
- diagnose the types of error made;
- deliver appropriate help to the student.

In the acceptance testing, first-year students who have used the Chinese Tutor, or seen a demonstration of it, thought that the Chinese Tutor could be helpful in the removal of native language influence in their study of Chinese. They agreed that this is a much more effective way of overcoming transfer errors than by merely doing exercises on their own.

In the expert testing, the expert on Chinese believed that first-year students should be able to benefit from the Chinese Tutor, since it is able to provide fruitful tutorials to help students overcome transfer errors.

11.1 Research Directions

There are several lines along which the Chinese Tutor could be further developed.

1. RESULT TESTING: a long-term evaluation [see *Chapter 10*] can be carried out by dividing the students into two groups. A comparative study is needed at the end of the evaluation to see how useful the Chinese Tutor has been in helping students to eradicate transfer errors.

2. FLEXIBLE STUDENT MODELLING: the student's learning history can be stored in a format from which human experts can easily extract information about certain aspects of the student. In order to make this happen, a

- The Chinese Tutor has a good knowledge of students' common errors in their first-year study of Chinese grammar. It uses this knowledge as a guide for its tutoring emphasis in order to help students to improve their standard of Chinese grammar.

- The students' errors of negative transfer – the most common errors observed in the students' learning of Chinese – can be effectively diagnosed by applying the grammatical rules in the Mixed Grammar. The Chinese Tutor can detect arbitrary transfer errors, including complicated transfer errors that other existing tools find difficult or impossible to locate automatically.

- The types of transfer error made by the student can be accurately inferred by the Diagnoser, thus making it possible for the Chinese Tutor to deliver appropriate help to the student.

- An appropriate tutorial strategy is selected according to the student's current and general performance on the mastery of a particular kind of grammatical rule. This will help the student to master the difficult grammatical points in Chinese grammar.

11.3 What Can it Offer Teachers?

The Chinese Tutor has the following to offer teachers:

- The system will save teachers time by correcting students' deep-rooted errors of negative transfer, thus freeing them for more advanced work.

- The teachers can revise and refine the teachers' teaching materials by checking the performance of the students, because the system will make a record of the students' results, such as the types of error they made, for the teachers to view at a later time.

- The record of the students' learning history kept by the system will provide some evidence to the teachers of how language is learned or acquired and what

strategies students are employing in their learning of the target language. This will help the teachers to gain some insight into how the students are progressing and can indicate to the teachers where or even how to change or improve their methods of teaching.

Glossary

abstract types: a section of code which appears to the application programmer as independent of any particular representation

adaptive maintenance: changes made in response to the changes in the environment in which the system operates

black-box testing: a technique of testing against the specification

bottom-up parsing: a parser that is mainly driven by data

bug catalogue: a method used for pre-storing errors which cannot be parsed by a parser

bug model: representing the student's misconceptions (bugs) by mal-rules as deviations from correct skills

cloze test: a test of the ability to comprehend text in which the reader has to supply the missing words that have been removed from the text at regular intervals

coaching method: providing students with an environment in which to engage in activities such as computer games in order to encourage skill acquisition and general problem-solving abilities

computer-aided design: the application of computer technology to the design of a product, or the design itself

computer-integrated manufacturing: the use of computers to control equip-

ment used in manufacturing systems

computer vision: the process of using computers to extract from images useful information about the physical world, including meaningful descriptions of physical objects

contrastive analysis: systematic comparison of two or more languages

corrective maintenance: the removal of residual faults but with the specifications unchanged

currying: a device for replacing structured arguments by a sequence of simple ones

developmental error: an error found in the course of learning either a first language or a second language

equivalence partitioning: a technique for determining which classes of input data have common properties

expert problem-solving system: a computer program built for commercial application using the programming techniques of artificial intelligence, especially those techniques developed for problem solving

flexibility: the ability to modify the system for different tasks in different domains

global transfer: the whole sentence is syntactically incorrect and the entire native language construction can be used to explain this kind of error

higher-order function: a function which takes a function as an argument, or delivers one as a result

inferencing mechanism: the technique or strategy used by the inference engine to access and apply the domain knowledge; that is, to make inferences based on the information in the data base

integration: building a system component so that it can be used to assist other

components of the system

Intelligent Language Tutoring System: a computer program that uses Artificial Intelligence techniques for handling problems in connection with a language or languages

Intelligent Tutoring System: a computer program that uses Artificial Intelligence techniques for representing knowledge and undertaking an interaction with a student

knowledge acquisition: a systematic process used by a knowledge engineer to discover the knowledge of a human expert, so that it can be incorporated in an expert system

language universals: structural features that all languages have in common

lazy evaluation: a function calling mechanism in which unevaluated expressions may be passed as arguments to any function only once, and it is regarded as the function's responsibility to evaluate those expressions as and when their values are needed

lexical error: a choice of a wrong character, or a made-up character by the student, or an incomplete character

lexical transfer: an error which can be explained by the direct translation of a word in the native language

Miranda: a pure functional language with non-strict semantics and a polymorphic type checking system

miscomprehension: the influence of the native language structures on the understanding of the target language

natural language processing techniques: techniques such as pattern matching and syntactic parsing used in the processing of utterances in human language (natural language as opposed to programming language) in order to extract meaning

and respond appropriately

overgeneralisation: over-extension or over-regularisation

overlay student modelling: a checklist indicating which of the procedural components of the expert model have been matched by the student

overproduction: the use of too many simple structures as a consequence of underproduction

pattern-matching model: monitoring the student's knowledge through pattern-matching that flags the topics that have been mastered by the student

perfective maintenance: changes demanded by the user which will improve the effectiveness of the system such as additional functionality or decreased response time

phrasal transfer: an error which can be easily explained by using a phrase in the native language

phrase structure grammar a kind of grammar which consists of a set of non-terminals, a set of terminals, a special start symbol belonging to the set of non-terminals, and a set of rewrite rules

pilot test: a test used to determine what effects a computer-based system will have before proceeding with implementation on a wider scale

procedural model: the use of a program to simulate the student's behaviour and develop hypotheses about his/her performance

production system: a knowledge-based system that represents knowledge in the form of production rules

procedural representation: representing knowledge about the world as procedures within the system

referential transparency: a property of a function signifying that evaluation

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Appendix A

Expert Questionnaire on Chinese Language

October 1991

The aim of this questionnaire is to elicit knowledge from human experts on the Chinese language. This knowledge will be used for the design of a language tutoring system which will help first-year students overcome common errors in their study of Chinese grammar. We do appreciate your support, which will benefit our research. Please tick the relevant box.

1. What kind of expertise have you got on Chinese?

   a. How long have you been teaching Chinese?

   b. What aspects of the language have you taught?

2. Have you seen your first-year students making the following types of error in their study of Chinese?

   ☐ syntactic transfer[1] such as: 我 看 报 在 图 书 馆

[1]Syntactic transfer 是 指 受 母 语 句 法 影 响 而 造 成 的 错 误 .

☐ phrasal transfer[2]: 教 授 张

☐ lexical transfer[3]: (你 的 电 话 号 码 是)什 么 or 穿 眼 镜

☐ overgeneralisation[4]: (这 座 楼 的)个 子 (很 高)

☐ syntactic error: 他 的 汉 字 写 得 可 差 !

☐ lexical error: (错 字 ,白 字 等)

other kind(s)(please specify):

3. How much do you think the grammar of the student's native language affects his/her learning of Chinese grammar?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

1 means very little 10 means a great deal

4. How important do you think negative transfer is in first-year students' learning of Chinese grammar?

☐ very important ☐ fairly important ☐ not important others:

5. What percentage of first-year students do you think are affected by negative transfer?

☐ all ☐ 80% ☐ 70% ☐ 50% ☐ 30% ☐ none

6. How does this percentage of first-year students compare with that of the second, third or fourth-year students?

---

[2]Phrasal transfer 是 指 受 母 语 短 语 影 响 而 造 成 的 错 误 .

[3]Lexical transfer 是 指 受 母 语 词 汇 影 响 而 造 成 的 错 误 .

[4]Overgeneralisation, also known as over-extension or over-regularisation, is a process common in both first and second language learning, in which a learner extends the use of a grammatical rule or linguistic item beyond its accepted uses, generally by making words or structures follow a more regular pattern.

☐ higher ☐ equal ☐ lower others:

7. Have you met with hard cases when the student cannot overcome his/her difficulties because of negative transfer?

☐ yes how many times:

☐ no

8. What kind(s) of tutorial techniques do you employ in assisting the students to overcome negative transfer errors?

☐ explain the topic to the student

☐ explain the error to the student

☐ explain the error by comparing the grammar of the native language with that of the target language (Chinese)

☐ correct the error for the student

☐ ask the student to correct the error

☐ provide the student with examples

☐ assign appropriate exercises

technique(s) of other kind:

9. Have you ever taught other languages apart from Chinese?

☐ yes which language(s): ☐ no

10. If yes, how important do you think negative transfer is in learning the above language?

☐ very important ☐ fairly important ☐ not important

others:

11. Any other observations or information on negative transfer that you would like to contribute? (Please write on a separate piece of paper if necessary)

Thank you very much for your cooperation.

Appendix B

Results of Expert Questionnaire on Chinese Language

1	A	3 AND A HALF YEARS	12 YEARS	2 YEARS	12 YEARS
	B	SPEAKING,LISTENING, READING,WRITING, TRANSLATION	SYNTAX,STYLISTICS, SCRIPT,LITERATURE, TRANSLATION	PRONUNCIATION, LISTENING,SPEAKING, READING & WRITING	ALL ASPECTS
2		1 2 3 6	1 2 3 6	1 3 5 6	1 3 5 6
3		5	5	8	8
4		FAIRLY	FAIRLY	FAIRLY	FAIRLY
5		50%	70%	70%	50%
6		HIGHER	EQUAL	HIGHER	HIGHER
7		YES	YES: MANY TIMES	NO	YES: BUT SELDOM
8		ALL	3 6	1 2 3 4 6	1 3 4 6
9		NO	YES: ENGLISH	YES: ENGLISH	YES: FRENCH
10		/	FAIRLY	FAIRLY	/
11		/	SEE 1	/	/

1: THE STUDENTS JUST NEED SYSTEMATIC DRILLS ON PARTICULAR SENTENCE PATTERNS WHICH ARE NOT (OR ENTIRELY DIFFERENT FROM) ENGLISH.

Table B.1: Results of Experts' Questionnaire I

1	A	20 + YEARS	5 YEARS	4 AND A HALF YEARS	4 YEARS	10 YEARS
	B	GRAMMAR	COMPOSITION, TRANSLATION & DRILL CLASS	GRAMMAR,LISTENING, INTERPRETING & SELECTED READING	GRAMMAR & COMPOSITION	MODERN CHINESE
2		12346	12456	ALL	1346	126
3		5	9	5	8	8
4		FAIRLY	FAIRLY	FAIRLY	FAIRLY	FAIRLY
5		ALL	80%	ALL	80%	ALL
6		LOWER	EQUAL	HIGHER	HIGHER	HIGHER
7		YES: SEE 1	NO	YES: MORE THAN ONCE	NO	NO
8		ALL	3457	367	257	ALL
9		YES: JAPANESE	NO	YES: ENGLISH	NO	NO
10		FAIRLY	/	FAIRLY	/	/
11		SEE 2	/	/	/	/

1: STUDENTS CONTINUE TO MAKE THESE ERRORS BUT WITH DIMINISHING FREQUENCY. A SMALL NUMBER, LESS THAN 5% SEEM COMPLETELY UNABLE TO ERADICATE SUCH ERRORS.

2: IT'S MORE OK A PROBLEM IN STUDENTS WITH A WEAK LANGUAGE LEARNING BACKGROUND AND IN MORE MATURE STDUENTS. MATURE STUDENTS WITH NO PREVIOUS LANGUAGE LEARNING BACKGROUND ARE THOSE WITH GREATEST NEGATIVE TRANSFER PROBLEMS.

Table B.2: Results of Experts' Questionnaire II

1	A	2 YEARS	4 TERMS	3 YEARS	1 YEAR	30 YEARS	18 YEARS	6 YEARS
	B	CONVERSATION	MODERN CHINESE	MODERN CHINESE	TRANSLATION	MODERN CHINESE & GRAMMAR	GRAMMAR & TRANSLATION	GRAMMAR & CONVERSATION
2		ALL	16	1356	13456	12356	ALL	1236
3		7	5	7	7	9	5	7
4		FAIRLY	FAIRLY	FAIRLY	VERY	FAIRLY	FAIRLY	FAIRLY
5		70%	50%	70%	70%	/	80%	70%
6		EQUAL	LOWER	HIGHER	HIGHER	EQUAL	HIGHER	EQUAL
7		NO	NO	NO	YES: 20% OF STUDENTS	/	YES: NOT OFTEN	NO
8		34567	13467	367	3456	3	ALL	234567
9		NO	ENGLISH	NO	NO	ENGLISH	ENGLISH	ENGLISH
10		/	FAIRLY	/	/	FAIRLY	FAIRLY	FAIRLY
11		/	/	/	SEE 1	/	/	/

1: IF THE NEGATIVE TRANSFER HAS BEEN PROPERLY TACKLED IN STUDENTS' FIRST YEAR STUDY OF CHINESE, WE WILL SEE A MUCH LOWER RATE OF TRANSFER ERRORS WHEN THEY MOVE TO THE SECOND AND THIRD YEAR.

Appendix C

Examples of Mixed Grammar of Chinese and English

The following is an example of what some verb phrases look like in the Mixed Grammar. A *verb phrase* can be a *coverb phrase*, a *copula phrase*, a *time_verb phrase*, a *modifier_verb phrase*, or a *passive_verb phrase.*

```
>verb_ph        = (perm ''verb_ph '') $n_
>                 coverb_ph $o_ copula_vp $o_ time_vp $o_
>                 modifier_vp $o_ passive_vp
```

A *coverb phrase* consists of a Chinese rule and an English rule. The Chinese rule is made up of a *coverb* followed by either a *noun phrase* or an *interrogative phrase.* The English rule contains a *copula* followed by the *interrogative phrase*, a *location phrase*, or a *demonstrative pronoun.*

```
>coverb_ph    =  (perm "coverb_ph ") $n_
>                  (coverb $t2_ (noun_ph $o_ interro_ph))
>                  $oet_ (copula $t2_ (interro_ph
>                    $o_ location_ph $o_ demon_pron))
```

A *copula verb phrase* is formed by a copula with either an *interrogative phrase* or a *noun phrase.*

```
>copula_vp    = (perm ''copula_vp '') $n_
>               copula $t2_ (interro_ph $o_ noun_ph)
```

A *time_verb phrase* contains a Chinese rule and an English rule. The Chinese rule is made up of a *time phrase* followed by either a *transitive verb phrase* or an *intransitive verb*; while the English rule is made up of a *time phrase* preceded by either a *transitive verb phrase* or an *intransitive verb.*

```
>time_vp      = (perm ''time_vp '') $n_
>               (time_ph $t2_ (trans_vp $o_ intrans_v))
>               $oet_ ((trans_vp $o_ intrans_v) $t2_ time_ph)
```

A *modifier_verb phrase* is made up of two parts. The function **p_** in the first part **p_ (auxiliary $o_ rep_ad)** is an optional function, which indicates that either the *auxiliary* or the *repetitive adverb*, or both can be omitted. The second part is made up of either a *prepositional_verb phrase* or a *disposal_verb phrase.*

```
>modifier_vp  = (perm ''modifier_vp '') $n_
>               (p_ (auxiliary $o_ rep_ad) $t2_ (prep_vp $io_
>                disposal_vp))
```

A *passive_verb phrase* is made up of a Chinese rule and an English rule. The Chinese rule consists of a *passive prepositional phrase* followed by a *passive structure*; while the English rule contains a *passive structure* and an optional *passive prepositional phrase.*

```
>passive_vp   = (perm ''passive_vp '') $n_
>               (pass_ph $t2_ pass_stru)
>               $oet_ pass_stru $t2_ p_ pass_ph
```

Appendix D

A Questionnaire for Potential Users (October 1993)

The aim of this survey is to find out what you think about the Chinese Tutor, after you have used the system or seen the demonstration. We do appreciate your support. Please tick the relevant box. Numbers 1 to 5 are used for indicating levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = no preference, 4 = agree and 5 = strongly agree.

1. Do you think it would be useful to have a Chinese tutoring system helping you overcome common errors in your first-year study of Chinese?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Do you think that interacting with a Chinese tutoring system can help you improve your Chinese more efficiently than doing exercises on your own?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Have you found the translation exercises provided by the Chinese Tutor useful?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. Do you think the additional exercises are helpful in mastering the grammatical rules which are found difficult?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Do you think the response of the system is fast enough?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. Do you think the feedback given by the system helpful?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. Have you found the Chinese Tutor easy to use?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

8. In general, have you found the Chinese Tutor helpful in overcoming errors of negative transfer?

☐ yes ☐ no

9. In your study of Chinese, have you come across any exercises which are specially designed for helping students overcome mother tongue influence? (If yes, could you specify where you have seen them and whether you found them helpful?)

☐ yes ☐ no

10. What other features would you like to see in a tutoring system?

Thank you very much for your time!

Appendix E

Student Feedback on "the Chinese Tutor"

Question 1: Do you think it would be useful to have a Chinese tutoring system helping you overcome common errors in your first-year study of Chinese?

Result A (from students who have used the Chinese Tutor):

5 5 5 5

Result B (from students who have seen the demonstration of the Chinese Tutor):

5 5 5 5 5 5

Question 2: Do you think that interacting with a Chinese tutoring system can help you improve your Chinese more efficiently than doing exercises on your own?

Result A: **5** **5** **4** **5**

Result B: **5** **5** **5** **5** **4** **5**

Question 3: Have you found the translation exercises provided by the Chinese

Tutor useful?

Result A: 5 5 4 5

Result B: 4 4 5 5 4 5

Question 4: Do you think the additional exercises are helpful in mastering the grammatical rules which are found difficult?

Result A: 5 5 3 4

Result B: 3 4 5 5 4 4

Question 5: Do you think the response of the system is quick enough?

Result A: 4 4 4 5

Result B: 3 4 5 5 3 4

Question 6: Do you think the feedback given by the system helpful?

Result A: 5 5 4 5

Result B: 4 4 4 5 3 5

Question 7: Have you found the Chinese Tutor easy to use?

Result A: 5 5 3 5

Result B: 4 3 2 3 3 4

Question 8: In general, have you found the Chinese Tutor helpful in overcoming errors of negative transfer?

Result A: yes yes yes yes

Result B: yes yes yes yes yes yes

Question 9: In your study of Chinese, have you come across any exercises which are

specially designed for helping students overcome mother tongue influence? (If yes, could you specify where you have seen them and whether you found them helpful?)

Result A: **no** **no** **no** **no**

Result B: **no** **no** **no** **no** **no** **no**

Question 10: What other features would you like to see in a tutoring system?

Result A:

One student put: "I can't think of anything else I would like to add, it seems excellent".

Another student put: "At the moment, I can't give any other features which may be useful, but once I have studied more, I may be able to help".

The eight other students did not answer this question.

Appendix F

A Questionnaire for Experts on Chinese (May 1994)

The aim of this survey is to find out what you think about the Chinese Tutor, after you have seen the demonstration. We do appreciate your cooperation. Please tick the relevant box. Numbers 1 to 5 are used for indicating levels of agreement: 1 = strongly disagree, 2 = disagree, 3 = no preference, 4 = agree and 5 = strongly agree.

1. Do you think the translation exercises provided by the Chinese Tutor are well designed?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. In your view, are the specially designed exercises effective in assisting students whose learning of Chinese grammar has been greatly affected by the grammar of English?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Is the Chinese tutor able to detect students' error types accurately?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. Do you think the feedback provided by the Chinese Tutor is appropriate?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Do you think the students will overcome mother tongue influence more quickly by using this kind of system than by doing exercises on their own?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. Is there any possibility that your department could use a language tutoring system such as the Chinese Tutor in tutorials?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. What other features would you like to see in a tutoring system?

Appendix G

completedQuestion abstype

The following is the abstract type for completedQuestion. A completed question is a question from a lesson (i.e. a sentence to be translated into Chinese) together with the student's translation of that question.

The student's translation (if it's a correct Chinese sentence) is compared with the standard translation in the function studentModel, which provides a result type to "score" the student's translation with. If the translation contains errors, the error types are classified. Every line of Miranda code is preceded by a >.

```
>abstype completedQuestion
>with
>   mkCompletedQuestion :: lessonSentence -> answer ->
>                          completedQuestion
>   mkQuestion :: lessonSentence -> completedQuestion
>   addAnswer :: completedQuestion -> answer -> completedQuestion
>   addResult :: completedQuestion -> result -> completedQuestion
>   getCQuestion :: completedQuestion -> lessonSentence
>   getAnswer :: completedQuestion -> answer
>   getResult :: completedQuestion -> result
>   isScoredQuestion :: completedQuestion -> bool
```

```
>completedQuestion == completedQuestion_t


>completedQuestion_t ::= UnAnswered lessonSentence
>                      | UnScored lessonSentence answer
>                      | Scored lessonSentence answer result
```

mkCompletedQuestion takes a lessonSentence (an abstract type) and a student's translation and creates a completedQuestion. This has no result yet, as it has not yet been passed to studentModel for scoring.

```
>mkCompletedQuestion q a = UnScored q a

>mkQuestion q = UnAnswered q

>addAnswer (UnAnswered q) a = UnScored q a
>addAnswer q a
>   = error ''Attempt to add a student's translation to a translation
>     exercise which has already been translated''
```

addResult takes an unscored completedQuestion and adds in a result type, obtained by scoring the student's translation in the function studentModel.

```
>addResult (UnAnswered q)
>   = error ''Attempt to add a result to an untranslated sentence''
>addResult (UnScored q a) r = Scored q a r
>addResult (Scored q a r) r
>  = error ''Attempt to add a result to a completed question which
>    already has one''
```

Selector functions for completedQuestion.

```
>getCQuestion (UnAnswered q) = q
>getCQuestion (UnScored q a) = q
>getCQuestion (Scored q a r) = q

>getAnswer (UnAnswered q)
```

```
>    = error ''Attempt to get a student's translation from an
>      untranslated sentence''
>getAnswer (UnScored q a) = a
>getAnswer (Scored q a r) = a

>getResult (UnAnswered q)
>    = error ''Attempt to get a result for an untranslated sentence''
>getResult (UnScored q a) = error ''Attempt to get result for
>                           unscored translation''
>getResult (Scored q a r) = r
```

isScoredQuestion is used to determine whether a student's translation is scored.

```
> isScoredQuestion (Scored q a r) = True
> isScoredQuestion x = False
```

Appendix H

result abstype

The following is an abstract type for result. This is the result of "scoring" the student's translation in studentModel. A translation is either a good parse, in which case a comparison result is returned (consisting of the results of the lexical comparisons) or is a bad parse, in which case the types of the error are returned as a list of type classifyResult. In both cases, the result also consists of a ruleMastered value.

```
>abstype result
>with
>   mkGoodParse :: comparisonResult -> ruleMastered -> result
>   mkBadParse :: [classifyResult] -> ruleMastered -> result
>   isGoodParse, isBadParse :: result -> bool
>   getComparisonResult :: result -> comparisonResult
>   getRuleMastered :: result -> ruleMastered
>   getClassifyResults :: result -> [classifyResult]
>   showresult :: result -> [char]


>comparisonResult ::= Poor|BelowAverage|Average|Good|Excellent

>ruleMastered == (rule, familiarity)

>rule == [char]
```

```
>familiarity == num

>classifyResult == ([char], typeOfError)

>result == result_t


>result_t ::= GoodParse comparisonResult ruleMastered |
>             BadParse [classifyResult] ruleMastered
```

mkGoodParse and mkBadParse are used to create values of the type result.

```
>mkGoodParse cr rm = GoodParse cr rm

>mkBadParse clr rm = BadParse clr rm
```

isGoodParse and isBadParse are used to determine whether the result of the parse is good or bad.

```
>isGoodParse (GoodParse cr rm) = True
>isGoodParse (BadParse cr rm) = False

>isBadParse (BadParse cr rm) = True
>isBadParse (GoodParse cr rm) = False
```

Selector and show functions for the result type.

```
>getComparisonResult (GoodParse cr rm) = cr
>getComparisonResult (BadParse clr rm)
> = error''Attempt to obtain a comparison result for the bad parse.''

>getRuleMastered (GoodParse cr rm) = rm
>getRuleMastered (BadParse cr rm) = rm

>getClassifyResults (GoodParse cr rm)
> = error''Attempt to obtain classified results for the good parse.''
```

```
>getClassifyResults (BadParse clr rm) = clr

>showresult (GoodParse x rm)
>    = ''Good parse: '' ++  show x
>      ++ ''\n'' ++ showruleMastered rm
>showresult (BadParse cr rm)
>    = ''Bad parse: '' ++ ''\n'' ++ lay (map showclassifyResult cr)
>       ++ ''\n'' ++ showruleMastered rm
```

Appendix I

Examples of Translation Exercises

The following are the translation exercises of one of the lessons for tutorials provided by the Chinese Tutor.

Lesson 24

1. I have finished using that English dictionary.
2. She has finished reading two Japanese books.
3. John has finished writing Chinese characters.
4. They have finished reviewing the German grammar.
5. The students have finished doing exercises.
6. We have finished watching TV.
7. I have finished buying stamps.
8. Qingqing has finished asking questions.
9. We have finished reviewing lesson five.
10. The students have finished listening lesson ten.

Appendix J

Examples of Standard Translations

The possible standard translations for the translation exercises of *Lesson 24* are presented in the following. The letters after the numbers such as *1a* indicate that there is more than one way of translating the sentence. The square brackets separated by a comma indicate a choice and round brackets suggest that a word (or a punctuation) or part of a word can be omitted.

Lesson 24

1a: 我 用 完 了 那 (一) 本 (儿) 英 [文 , 语] 词 典 .

1b: 我 用 完 (了) 那 (一) 本 (儿) 英 [文 , 语] 词 典 了 .

1c: 那 (一) 本 (儿) 英 [文 , 语] 词 典 (,) 我 用 完 了 .

2a: 她 [看 , 读] 完 了 两 本 (儿) 日 [语 , 文] 书 .

2b: 她 [看 , 读] 完 (了) 两 本 (儿) 日 [语 , 文] 书 了 .

3a: 约 翰 写 完 了 汉 字 .

3b: 约 翰 写 完 (了) 汉 字 了 .

3b: 汉 字 (,) 约 翰 写 完 了 .

4a: [他 ,她]们 复 习 完 了 德 [语 , 文] 语 法 .

4b: [他 ,她]们 复 习 完 (了) 德 [语 , 文] 语 法 了 .

4c: 德 [语 , 文] 语 法 (,) [他 ,她]们 复 习 完 了 .

5a: 学 生 (们) 做 完 了 练 习 .

5b: 学 生 (们) 做 完 (了) 练 习 了 .

5c: 练 习 (,) 学 生 (们) 做 完 了 .

6a: [我 们 , 咱 们] 看 完 了 电 视 .

6b: [我 们 , 咱 们] 看 完 (了) 电 视 了 .

6c: 电 视 (,) [我 们 , 咱 们] 看 完 了 .

7a: 我 买 完 了 邮 票 .

7b: 我 买 完 (了) 邮 票 了 .

7c: 邮 票 (,) 我 买 完 了 .

8a: 青 青 问 完 了 问 题 .

8b: 青 青 问 完 (了) 问 题 了 .

8c: 问 题 (,) 青 青 问 完 了 .

9a: [我 们 , 咱 们] 复 习 完 了 第 五 课 .

9b: [我 们 , 咱 们] 复 习 完 (了) 第 五 课 了 .

9c: 第 五 课 (,) [我 们 , 咱 们] 复 习 完 了 .

10a: 学 生 (们) 听 完 了 第 十 课 .

10b: 学 生 (们) 听 完 (了) 第 十 课 了 .

10c: 第 十 课 (,) 学 生 (们) 听 完 了 .

Appendix K

Examples of Pair Choice Exercises

Pair choice exercises are additional exercises which comprise a correct and an incorrect Chinese sentence. The student is asked to identify the correct one. The following are pair choice exercises for *Lesson 25a*.

Pair Choice Exercises

Lesson 25a

Exercise 1:

(Which of the two sentences below is the correct translation of: "His room is very clean"?)

A. 他 的 房 间 是 很 干 净 .

B. 他 的 房 间 很 干 净 .

Exercise 2:

(Which of the following two sentences is the correct translation of: "Prof. Li is

very angry"?)

A. 李 教 授 很 生 气 .

B. 李 教 授 是 很 生 气 .

Exercise 3:

(Which of the following two sentences is the correct translation of: "That doctor is very young"?)

A. 那 个 医 生 是 很 年 轻 .

B. 那 个 医 生 很 年 轻 .

Exercise 4:

(Which of the two sentences below is the correct translation of: "His Chinese friend is very polite"?)

A. 他 的 中 国 朋 友 是 很 客 气 .

B. 他 的 中 国 朋 友 很 客 气 .

Exercise 5:

(Which of the two Chinese sentences is the correct translation of: "Your clothes are verb clean"?)

A. 你 的 衣 服 很 干 净 .

B. 你 的 衣 服 是 干 净 .

Appendix L

Examples of Sentences Built-Up from Constituents

The following are additional exercises of sentences built up from constituents for *Lesson 25a.* The student is asked to put the sentence in the right order.

Exercises 1:

pronoun	noun	particle	noun	adverb	adjective
他	妹妹	的	房间	很	干净
1	2	3	4	5	6

Exercise 2:

demonstrative pron.	measure word	noun	adjective	adverb
那	个	小孩儿	生气	很
1	2	3	4	5

Exercise 3:

adjective	pronoun	proper noun	particle	noun	adverb

客气	他	中国	的	朋友	很
1	2	3	4	5	6

Exercise 4:

demonstrative pron.	measure word	adverb	adjective	noun
这	个	很	贵	照相机
1	2	3	4	5

Exercise 5:

demonstrative pron.	measure word	noun	adverb	adjective
这	个	书架	很	重
1	2	3	4	5