A COMPUTATIONAL MODEL OF TENSE SELECTION AND ITS EXPERIMENTATION WITHIN AN INTELLIGENT TUTOR

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ABSTRACT. The paper presents a new computational model for the selection of verb tenses aimed at supporting the choice and conjugation of the appropriate tense in English sentences. The work has been developed within the framework of the ET research project whose purpose is the experimentation of intelligent tutoring systems for foreign language teaching. The model has been validated and experimentally tested through the development of TEN-EX (TENse EXpert), a prototype system which receives in input a representation of an English sentence and is capable of finding and conjugating the appropriate tense(s) for it. The model originates from the functional-systemic approach to tense from which it inherits the basic ideas of tense opposition and seriality. The model is characterized by some original assumptions such as the partitioning of the tense selection process in two separate phases aimed at discovering the 'objective' tense, relating speaking time to event time, and at mapping the objective tense into the actual grammatical tense. This bipartite organization corresponds to the idea that the tense selection process is influenced by both the temporal semantics of the situation a speaker intends to describe and the pragmatic and syntactic features which act as a filter in mapping the objective tense into the grammatical resources of the language at hand. TEN-EX is a fully implemented system which is currently capable of solving more than 80 exercises covering all the English indicative tenses.

1. Introduction

The study of the verb tense has traditionally arisen the interest of linguists and philosophers concerned with the semantics of natural language. Linguists have tried to describe the properties (at the morphological, syntactical or semantic level) of the tense in the different languages, while the philosophers have attempted to characterize its usage conditions. More recently, however, the issue of tense has attracted the attention of people interested in the construction of systems capable of automatic natural language processing since the tense of the verb plays a major role in the possibility of describing - and in understanding the description of - complex events. (For some recent collection of papers on this topic see: Dahl 1985; Dowty, 1986; Tedeschi and Zaenen 1981; Webber, 1988).

Our interest for the issue of tense has a different source since it originates from the efforts to construct intelligent tutoring systems for foreign languages. In the last few years we have built different versions of ET, a prototype tutor capable of supporting the learning of the English tense system (Fum, Giangrandi, and Tasso 1988, 1990; Fum, Pani and Tasso 1991, in press). As it is known, a fundamental component of a tutoring system is represented by the so called domain-expert module which incorporates the knowledge constituting the system expertise that has to be transmitted to the student. In the domain of tutoring systems for foreign languages, this module is supposed to incorporate the knowledge underlying the competence of a native speaker, in our case the system of rules supporting the use of English tenses.

In the paper we present a new computational model for the selection of tense which has been validated and experimentally tested through the development of TEN-EX, a prototype system capable of solving the tense generation problem. More particularly, the system, after receiving in input a schematic representation of an English sentence, finds and conjugates the appropriate tense(s) for it. The model originates from the functional-systemic approach to tense from which it inherits the basic ideas of tense opposition and seriality. The model is characterized by some original assumptions such as the partitioning of the tense selection process in two separate phases aimed at discovering the 'objective' tense relating speaking time to event time, and at mapping the objective tense into the actual grammatical tense, respectively. This bipartite organization corresponds to the idea that the tense selection process is influenced by both the temporal semantics of the situation a speaker intends to describe and the pragmatic and syntactic features which act as a filter in mapping the objective tense into the grammatical resources of the language at hand.

The paper is organized as follows: The next section illustrates the systemic approach to tense developed theoretically by Halliday (1976) and, from a computational point of view, by Matthiessen (1983, 1984). In the section some criticisms to the Matthiessen's approach are raised which motivate the development of our original model. Section 3 is devoted to the presentation of the new model from the theoretic point of view, to the discussion of its basic assumptions, and to the description of the knowledge it relies upon. Section 4 deals with the implementational aspects of TEN-EX in which the theoretical model has been realized, and provides an example of interaction with the system giving an idea of its capabilities. Section 5 ends the paper by making a general evaluation of the model and by suggesting some guidelines for future research.

2. The Systemic Theory of Tense

In this section the systemic approach to the problem of tense selection is briefly described. What follows is based on the work of Halliday (1976) and, in particular, of Matthiessen (1983, 1984).

According to the systemic approach, two assumptions are made concerning the grammar of the English tense. These assumptions are:

a) *Tense opposition:* the tense in English is considered as a three term opposition of past vs. present vs. future.
b) *Seriality:* complex tense combinations can be constructed by repeatedly selecting among the three term opposition.

The two assumptions reduce the process of tense selection to a series of iterative choices within the three terms option. In other words, a tense combination like *'is going to have built'* is chosen by picking up the first time *(primary tense)* the present, then *(secondary tense)* the future and finally *(ternary tense)* the past. The name for a tense combination in the systemic approach is determined by considering the inverted order of the choices: in our case the tense combination is a *past-in-future-in-present.*

Halliday identifies a series of 'stop rules' which capture the restrictions that the English grammar puts on the usage of tense and state which possible tense combinations are admissible. An important consequence of the rules is the fact that up to quinary tenses (like: *'will have been going to have been taking'* : a present-in-past-in-future-in-past-in-past) are allowed by the grammar. The rules define whether a tense combination is legitimate but they do not indicate *how* a given tense combination is selected. To this end, a significant contribution has been given by Matthiessen with his notion of *chooser.* To each option concerning the tense, Matthiessen assigns a procedure (or chooser) that states how the selection among the options specified is controlled.

According to this point of view, a verb tense essentially indicates the temporal relationship which holds between the so called *speaking time Ts* (i.e., the moment in which a sentence is uttered) and the *event time Te* (i.e., the moment in which the action or event described in the sentence is supposed to happen), and the tense selection process is based on such a relation. More particularly, for each iteration step, the choosers take into account a relation of precedence (anteriority) - that we symbolize through '<' - between two different temporal variables called the *reference time (Tr)* and the *comparison time (Tc),* respectively. If:

- *Tr* come after *Tc* $(Tc < Tr)$, then the past is chosen;
- *Tr* comes before *Tc* $(Tr < Tc)$, then the future is chosen;
- otherwise the chosen tense is the present.

The process starts by setting the time variable *Tr* to the speaking time *Ts* and by looking for the comparison time *Tc,* i.e., the time interval the speaking time is related to. At this point it is possible to choose the primary tense according to the relation which holds between the values of *Tr* and *Tc*. If the comparison time matches the event time *Te,* then the temporal link between *Ts* and *Te* has been found, and the resulting tense combination consists only of a primary tense (a simple present or a simple past or a simple future). If, on the other hand, the comparison time is different from the event time, the process cannot terminate since no temporal link has been established between the speaking time and the event time. A new iteration cycle starts by assigning the old value of *Tc* to *Tr* , which becomes the new *reference time,* and by looking for a new value of the comparison time *Tc.* The choice of the secondary tense is made again according to the relation holding between *Tr* and *Tc,* and the process terminates if *Tc* matches *Te.* If this is not the case, the process goes on according to the same modalities with a tertiary, quaternary or quinary tense, until a link between the speaking time and the event time is found.

Two points should be emphasized at the end of this description of the systemic grammar of tense. The first concerns the fact that, in the Matthiessen's approach (1983, 1984) the identification of the comparison time - which represents, according to our point of view, the most critical step in the tense selection process - is a process that falls outside the grammar since it is a question that ultimately concerns text planning: the choice of the temporal relations among different times depends in fact on the meaning a given utterance is intended to convey. This will represent, as we shall see below, a critical issue in our treatment of tense.

The second point concerns the semantics of tense. According to Matthiessen, the verb tense expresses a temporal link between the speaking time and the event time. These two times are directly connected in the case of a primary tense; they are associated through the mediation of one, two, three, or four intervening times in the case of secondary, ternary, quaternary and quinary tenses, respectively. Differently from Halliday, however, the fact that no tense exists beyond the quinary depends on reasons of meaning and text planning, not on grammatical motives. Other approaches (among these the classic account of Reichenbach (1947) claim that the temporal structure is restricted to three elements, i.e, the speaking time, the event time, and *one* reference time. According to Matthiessen, a three time account is inadequate for English for two reasons: First, it would limit the coverage of the grammar to secondary tenses. Second, there is no logical basis for arbitrarily restricting the temporal structure to three (instead of, say, five, two or six) different times.

The ideas which Matthiessen's proposal is grounded upon (i.e., the temporal chaining, and the criteria for selecting the tense and terminating the process) are simple and appealing. There are however some difficulties with this approach.

The main criticism which can be raised against the model concerns one of its major assumptions, i.e. the fact that the selection of a given tense in each iteration step depends on the precedence relation which exists between the current reference and the comparison times. Taken in its strong form (the selection depends *only* on the precedence relation) this assumption is simply wrong since it does not allow to capture all the subtleties and nuances of meaning which can be expressed through the appropriate use of English tenses. Taken in its weaker form (the selection depends *primarily* on the the precedence relation - allowing thus the exploitation of other kinds of knowledge) it conflicts with the orthodox systemic approach in which the roles of the different features are clearly defined and ordered. Let us clarify this point through some examples.

If we look at how the Matthiessen's chooser of the primary tense really works, we realize that the first test the chooser makes about the incoming clause concerns its counterfactuality (which is obviously a non-temporal aspect). If the clause expresses a counterfactual meaning, then the chosen tense is the past, otherwise a new test concerning whether the clause denotes any logical or temporal restriction is made. Only after this second test has been executed, a direct comparison between the *Tr* and *Tc* is performed. It is clear that the criterion of counterfactuality and the existence of logical or temporal restrictions introduce in the process of tense selection some factors that go beyond the precedence relation between the current reference and comparison time.

Another critical case for the model concerns the so-called futurate use of the simple present in sentences like:*We live home at six, arrive in London at midnight and take a plane to Amsterdam.* According to the model, since the event time comes after the speaking time, the future tense, instead of the present, should be chosen. The explanation Matthiessen gives to this 'anomaly' is not completely convincing: "My claim is that one reason for choosing the present is that there is a plan (which is executed at some time in the future, often adverbially specified) and what is important is that the plan is present. In other words, the relevant time is the time of planning not the time of execution and it is the relevant time that is *present* (i.e., located at *Ts)* " (1984, pg. 92). Matthiessen thus introduces a time associated with the planning activity and, in order to terminate the selection process with the simple present, forces the time of planning to coincide with the speaking time. The event in such a way almost disappears being substituted by its planning.

In summary, Matthiessen's model constitutes a useful approach to a computational treatment of the English tense within the systemic framework but, by concentrating almost exclusively on the role of a particular temporal relation, it falls short of providing a clear picture of the factors that play a significant role in the process of tense selection. It is on this point that we provide our original contribution.

3. A New Computational Model of Tense Selection

The computational model we propose divides the tense selection process in two separate phases, each phase exploiting knowledge of a different kind.

The first phase is devoted to determine the relationship a speaker intends to establish between the speaking time and the event time. This phase ends with the identification of the so-called *objective tense,* a conceptual, extra-linguistic entity which reflects the semantics of the situation the clause (or sentence) is intended to convey. The procedure for the determination of the objective tense follows the systemic model, i.e. it is performed through an iterative process whose choices are made sequentially within the opposition past vs. present vs. future according to the precedence relation between a given reference time and its comparison time. The process obviously terminates when the comparison time matches the time of the event, thus indicating that a link between the speaking time and the event time has been found. Depending on the number of intervening times, the objective tense - as it has been demonstrated by Matthiessen (1984) - can theoretically range from the primary to the quinary.

The main problem to be solved in this phase is that of identifying, for each iteration step, the time to which the reference time has to be compared. Once the reference time and the comparison time have been determined, in fact, the choice within the three term opposition is performed - following Matthiessen's algorithm - according to the precedence relation existing between them. However, while Matthiessen considers the identification of the comparison time as concerning the text planning activity, and does not therefore include it in his model, in our approach we deal directly with this problem. In particular, we solve it by relying on a set of rules which exploit a group of features of exclusively semantic nature. The most important among these features are those involving the temporal relations between the actions or events described in the sentence. These relation are expressed utilizing the temporal logic developed by Allen (1984). Other features that are taken into account by the rules identifying the comparison time concern the aspectual perspective, i.e., the point of view the speaker adopts in order to describe the situation, and the conceptual status of the events or states described in the sentence (for instance a state can be a consequence of an event, it can represent an enablement condition for the occurrence of an action, etc).

The second phase of the tense selection process is devoted to map the objective tense into the grammatical one. In this phase, the temporal link which exists between the speaking time and the event time is expressed through one of the tenses allowed by the grammar of the language at hand. This is a purely linguistic process and is deeply influenced by the resources of the language. Different languages have in fact different tense systems, and the mapping between the objective and the grammatical tense is generally not one-to-one. Sometimes, in absence of the appropriate grammatical tense, in order to express a given objective tense it is necessary to resort to some periphrastic expression. For example a present-in-past-in-present can be directly realized in English through a present perfect continuous *(I have been trying to finish this letter)* while in Italian the speaker has to choose between a 'passato prossimo' *(Ho* *tentato di finire questa lettera)* and a periphrasis *(Sto tentando di finire questa lettera),* conveying thus different nuances of meaning.

The choice of a given grammatical tense, however, does not express (and is not determined by) only the objective tense. Through the usage of a given grammatical tense it is possible to indicate some subtle distinctions and pragmatic implications. We have examined in the previous section the case of the futurate use of the present to suggest the idea that the action expressed by the verb has been already planned. To make another example, in English the use of the present continuous to describe an habitual action *(You are always asking me silly questions)* implies that the action annoys or seems unreasonable to the hearer.

The mapping between the objective and the grammatical tense is performed in the model by another set of rules which exploit a series of language-dependent features of morphologic, syntactic and pragmatic nature that act as a filter in translating a semantic relation into the idiosyncratic characteristics of the language. Among these feature we mention, in the case of English, whether the verb accepts the ing-form (a morphological feature), whether the sentence is a subordinate temporal (a syntactic feature), and whether the register is formal or informal (a pragmatic feature). The existence of these features influences how a given objective tense can be expressed. So, for example, a future event described in a temporal subordinate can be represented through the simple present *(I will stay in bed till the clock strikes seven),* and in the informal context the present continuous can be used to refer to a future action *(We are getting married in June).*

4. The TEN-EX Prototype

The model has been experimented and validated by developing a new prototype (called TEN-EX) of the domain expert for the English tense system. TEN-EX is capable of solving exercises which contain some verbs in infinitive form that have to be substituted by the correctly conjugated tense. The coverage of the system includes only tenses of the indicative form, up to the ternary level (quaternary and quinary tenses, although possible, are very uncommon).

For validating the performance of TEN-EX, a specific corpus has been developed, which includes 80 exercises selected from English textbooks, which have been certified with respect to the following requirements: non-ambiguity of the solution, full coverage of the indicative tenses, reliability of the contextual definition. In TEN-EX the exercises are internally represented by means of an *exercise description* containing a (sub)set of the features necessary for the tense generation process.

The functional architecture of TEN-EX (illustrated in figure 1) is organized around seven *Experts,* each one devoted to a specific part of the overall processing. The Experts are grouped into the following four main modules:

1. *Pre-processing Module,* devoted to augment the (partial) exercise description stored in the Exercise Database with other features which are automatically derived by the system. More specifically, the extension is performed by:
   - a *Temporal Expert,* which is capable of inferring all the temporal relations which exist among the states or events (and the temporal expressions) mentioned in the current exercise and that are not covered by the description. The Temporal Expert is also capable of checking the consistency and the completeness of such temporal relations. The overall temporal description of the exercise can also be transferred to the *User Interface,* in order to be displayed to the user.
   - an *Action Kind Expert,* which determines the correct class of each verb present in the current exercise on the base of the lexical information present in the Dictionary and of the specific contextual information extracted from the exercise description.
2. *Semantic Module,* which constitutes, together with the Linguistic Module, the kernel of the TEN-EX prototype. The operation of this module is based on the temporal relations and on the other semantic features characterizing the exercise (in accordance to the model presented in the previous section) and is aimed at performing the successive choices between past, present, and future which allow the identification of the objective tense. As already mentioned, we have limited the coverage of TEN-EX to ternary tenses, and therefore three

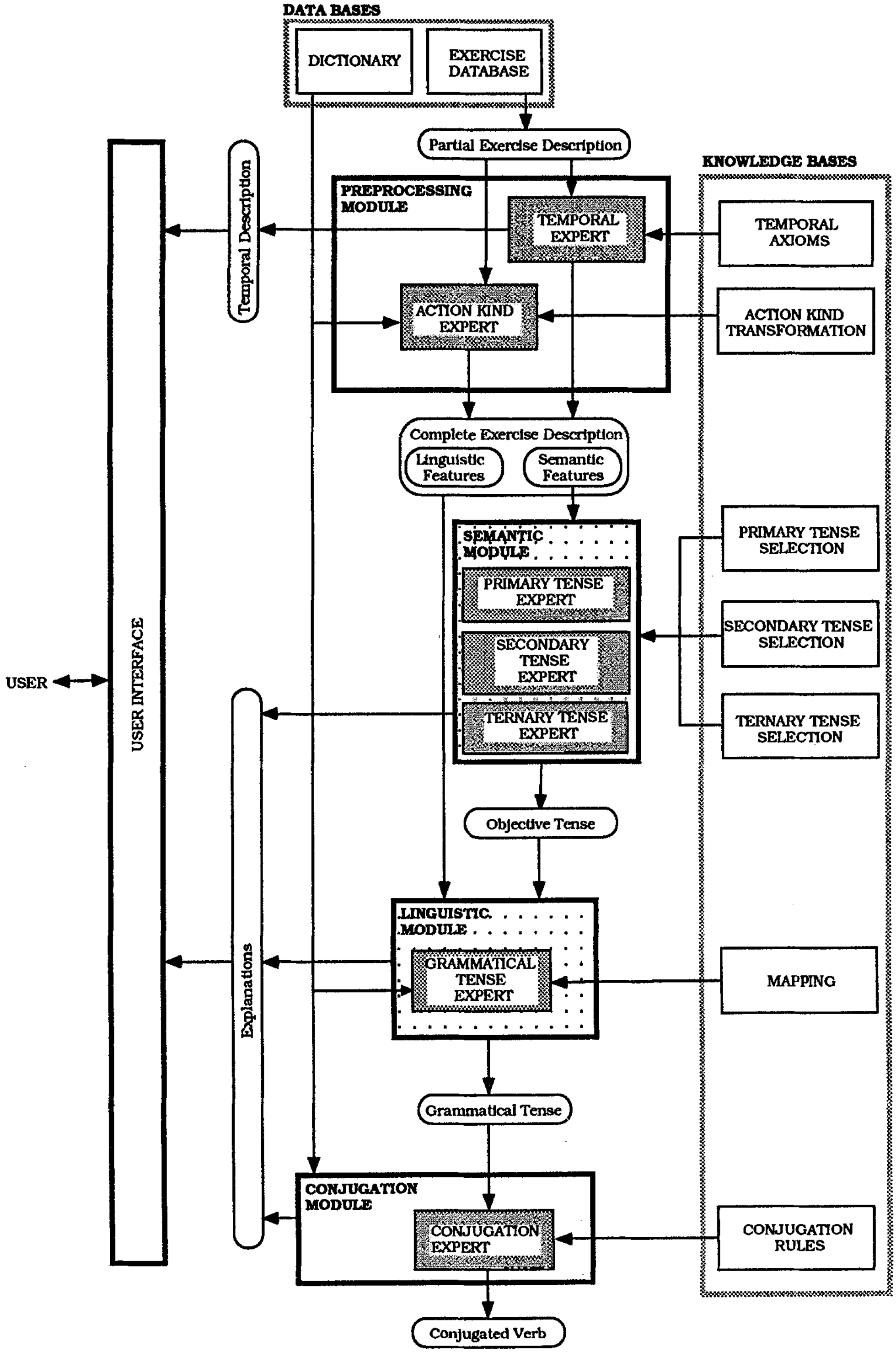

Figure 1. TEN-EX functional architecture.

specific Experts have been utilized, called *Primary, Secondary,* and *Ternary Tense Expert,* respectively. Each expert is in charge of identifying the correct comparison time, to perform the comparison with the reference time and the subsequent temporal selection, and to check whether the full link between speaking time and the event time has been established by verifying if the comparison time coincides with the event time. The Semantic Module has also the capability to provide detailed explanations on its behavior by tracing the derivation process of the objective tense.

3. *Linguistic Module,* devoted to perform the linguistic filtering mentioned in the previous section. The Linguistic Module includes a *Grammatical Tense Expert,* which is capable of mapping the objective tense into the correct grammatical one by taking into account the specificity of the language. It operates by considering the linguistic features describing the exercise together with Dictionary information. This module is also capable of producing explanations about the inferences carried on.
4. *Conjugating Module,* devoted to generate the final form of the verb considered in the solution process. It includes a *Conjugation Expert,* devoted to conjugate the verb into the appropriate tense.

The architecture includes also:

- a *User Interface,* which manages the interaction with the user and is capable of: (i) accepting from the user his/her choices about the specific exercise to be solved; (ii) graphically displaying to the user the temporal description of the exercise; (iii) showing to the user intermediate and final results of each processing phase; and (iv) displaying to the user (possibly at two different levels of abstraction) explanations about the internal inferences. This last capability has received a lot of attention, since the TEN-EX prototype has to be integrated within the ET environment where the capability of explaining how a result is obtained plays a fundamental role. The interface is implemented by means of multiple windows, pop-up menus, and mouse.

The operation of TEN-EX is supported by several knowledge bases devoted to specific tasks within the overall processing. All the knowledge is represented by means of production rules. In particular, as illustrated in Figure 1, for each Expert a specific knowledge base has been utilized, which contains only the knowledge relevant to it. We concentrate here only on the knowledge bases supporting the Semantic and the Linguistic Modules. More specifically, the three knowledge bases devoted to the identification of the objective tense are constituted by the rules in charge of the choice of the comparison times. An example of such a rule is the following:

IF the proposition introduces a new temporal context
the action described is a process
the event time includes the speaking time
THEN the comparison time is NOW.

As far as the Linguistic Module is concerned, most of its rules utilize the standard correspondence between systemic tenses and grammatical tenses. Specific rules, derived from English grammars, have also been included which capture morphologic, syntactic, and pragmatic knowledge about the usage (limitations, restrictions, exceptions, etc.) of tenses. An example of such a rule is the following:

IF the objective tense is present
the action described is habitual
the action described is insistent
the verb accepts the ing-form
THEN the grammatical tense is the present continuous

The system includes also the following two databases:

- the *Exercise Data Base,* which contains texts and descriptions of the exercises included in the above mentioned corpus, and
- a *Dictionary,* storing all the lexical information needed during the processing.

The TEN-EX prototype has been developed in LPA PROLOG on a Macintosh. At the implementation level (not shown in figure 1), the reasoning activity of the Experts is supported by two inference engines (one working in forward chaining and the other in backward chaining) and by a common working memory for the input and output data. A specific module, called *Supervisor*, is in charge of managing the overall operation of the system by assigning control to the expert currently exploited.

We conclude the section by briefly describing the overall operation of TEN-EX. In figure 2, 3, 4, and 5 we show some screens during a working session with TEN-EX. Operations are started by the Supervisor which assigns control to the User Interface in order to let the user choose the exercise to work with (this step will be modified when TEN-EX will be fully integrated with the ET tutoring system, and a specific module will take care of the selection of exercises) and the desired level of explanation. Then the exercise description is extracted from the Exercise Database and stored in the working memory. Control is subsequently assigned to all the Experts in the same order used in the above illustration. Each expert finds in the working memory the partial results produced by the previous one and, by exploiting an inference engine on the relevant knowledge base, contributes to the final solution. These partial solutions are displayed to the user, which may possibly ask for further explanations about the specific rules utilized. The operation terminates when the Conjugation Expert produces the final answer to the exercise.

The figures 2 to 5 refer to the solution of the exercise: "*He was busy packing, for he (leave) that night*". Figure 2 shows the temporal description of the exercise. Figure 3 shows some of the successive steps of the identification of the objective tense. In this case the objective tense is the future-in-past which, according to the standard correspondence between systemic tenses and grammatical tenses, should be mapped into the *'to be going to' (past)* form. However, the Linguistic Expert modifies this choice since verbs indicating movement or position (like *to leave*) prefer the past continuous (provided that the sentence includes a specific temporal expression), as illustrated in Figure 4. Figure 5 shows the final solution to the exercise.

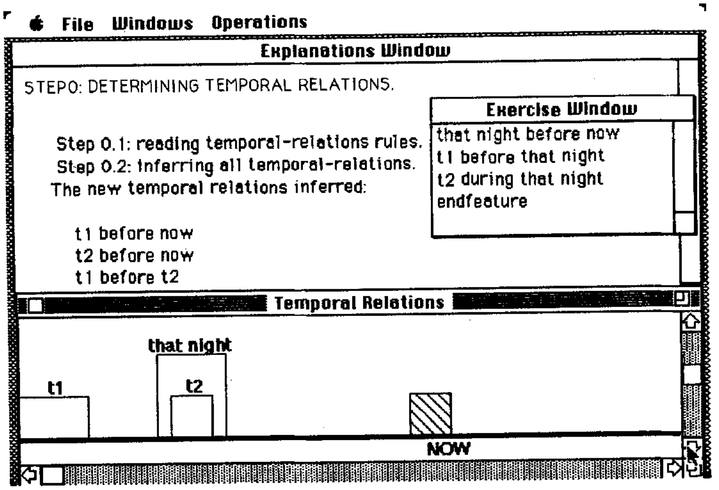

Figure 2. Determining and displaying temporal relations.

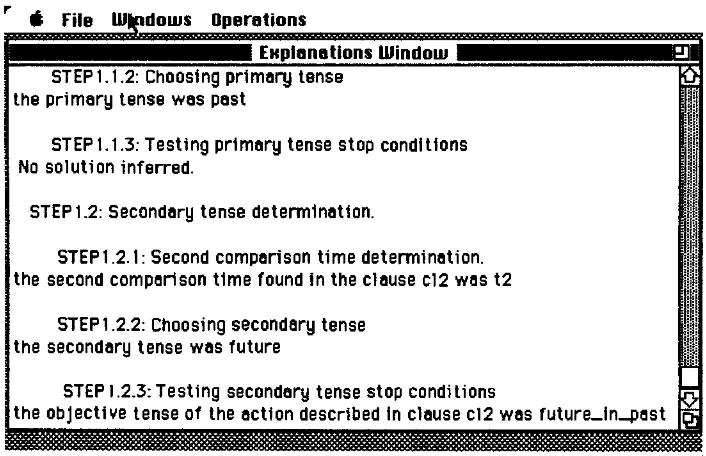

Figure 3. Identifying the objective tense.

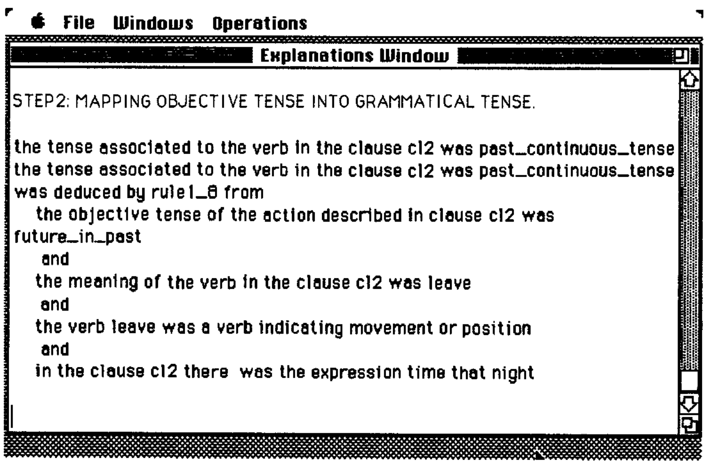

Figure 4. Mapping the objective tense into the grammatical tense.

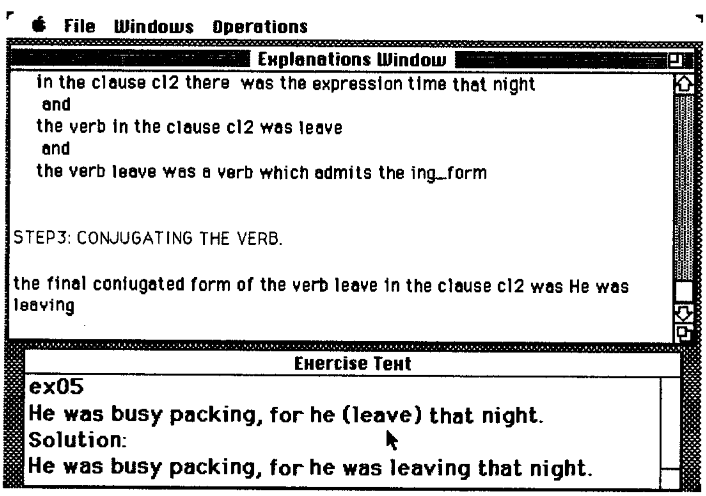

Figure 5. The conjugated tense.

5. Conclusions and Guidelines for Future Research

In the paper a new model for tense selection has been presented which has been implemented into the TEN-EX prototype, a system capable of selecting and conjugating the appropriate tense for English sentences. In comparison with existing models based on the systemic approach, our model clearly separates the identification of the semantic relations existing between the speaking time and the event time from the mapping of such relations into the grammatical tense and moreover it clearly specifies the role of the morphological, syntactic, semantic, and pragmatic features in the process of tense selection.
As a result of the bipartite organization, a level of generality has been achieved which should facilitate the portability of the model to other languages. Building an expert for a language different from English, in fact, would require only the of the construction of a new linguistic filter, being the semantic module left untouched. Several future research perspectives have been disclosed by the development of the model, including (a) the need to validate the approach from a pedagogic point of view; (b) the extension to other languages; and (c) the extension of the system capabilities with respect to the automatic derivation of the exercise description from the natural language text.

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