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HAL Id: edutice-00674156
https://edutice.hal.science/edutice-00674156

Submitted on 25 Feb 2012

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Abstract: The results of past studies in Error Analysis in applied linguistics and the experiences of developers of intelligent tutoring systems in learner modelling have influenced our definition of a new structure, called an "applicable rule", that can be used to help diagnose and to represent a learner's performance in second language learning systems. Based on this structure a prototype interface has been designed to acquire the knowledge that it must contain. The results of experiments with this interface, to validate and to fill it, have been instrumental in refining its structure, pointing out the difficulties of transforming it into an automated acquisition device, and in indicating its potential as a teaching device.

Keywords: Learner modelling, Intelligent Tutoring System, Second Language Learning, Knowledge Acquisition

1.   Introduction

Computer-based learning environments that adapt sensitively to a learner require current methods of learner modelling to be improved. Generally speaking, earlier approaches to learner modelling in intelligent tutoring systems (ITSs) took account only of the immediately observable performance giving little or no consideration to the deeper underlying causes of the production of this behaviour. Without an understanding of these underlying misconceptions a more responsive adaptation of the environment to the learner is severely limited.

In pursuing a deeper modelling approach in second language learning we have followed the current approach of the applied linguistic community in viewing second language learning (SLL) as one of building and updating rules for language production through the use of heuristics and various strategies brought about by the circumstances in which learners find themselves, e.g. a pressing need to communicate. The process of learner modelling is to identify, not only this set of rules, but also their causal mechanisms, the learner's heuristics and strategies, that are currently active.

In order to represent these aspects of learner modelling we introduce the idea of an *applicable rule* (AR). This term stems from the concept of rules being modified to fit a particular situation and thus being seen as applicable to this situation. The applicable rule approach de-emphasises the idea of absolute correctness. This is desirable for several reasons: firstly, because we wish to encourage a learner's internal generation of applicable rules as a valuable part of learning, even if this leads at times to incorrect rules; secondly, because teachers themselves may wish to use applicable rules, as pedagogic devices to encourage learning, accepting the approximation to the desired language competence; and thirdly, the domain of language learning is less clear cut than those traditionally used for ITSs, such as mathematics or programming languages; hence correctness can depend on how the language is being used, for instance in speech or writing.

This paper outlines the development of an interface that is a support tool for acquiring from language teachers their knowledge about why a learner produces a foreign language in certain ways. The design of this interface is based on an applicable rule framework that encapsulates the information necessary to diagnose how and why a learner has produced a particular sentence that diverges from that expected. The information collected from experiments with this interface, which is an early development stage in an evolving system, we call BELLOC, has led to the refinement of the structure of an applicable rule and to the design of an architecture (detailed in [2]) to support the computer diagnosis of a learner's grammatical performance. As a by-product of this exercise we are able to suggest ways in which the interface could be used in an instructional role.

2.   An applicable rule, a structure for learner modelling

Many past ITSs have modelled the learner by a set of production rules which describe at some level of detail the possible "bugs" that a learner may have, where a bug is the discrepancy between the system's representation of a learner's behaviour in some problem solving situation and the system's conception of what that behaviour should be. Typically the anticipated discrepancies are held in a bug catalogue which has been prepared by observation and the meticulous analysis of learner's past performances. The development of these bug catalogues (which can run into several hundred rules) is labour intensive and is a task that can stretch over several years [1]; it thus presents severe problems in modelling learners. Additionally, bug catalogues are concerned with relatively superficial differences in behaviour and not with the underlying misconceptions that gave rise to the bugs. It is the identification of these misconceptions that could guide more sensitively further interactions with the learner.

In second language learning this problem has been extensively investigated. The emphasis on deeper explanation of learners' performance has come from Error Analysis in applied linguistics where, starting with studies in the early 1970s [5], second language learners were seen as actively constructing rules from the data they encountered, gradually adapting them in the direction of the target language system. This meant that the learners' errors needed no longer to be seen as signs of failure. On the contrary, they gave some evidence for the learners developing their systems of rules. Arising from these studies different cognitive processes were proposed that gave possible explanations of errors [4]. The commonly known one is that of language transfer where the learner uses his mother-tongue (or sometimes knowledge of another foreign language) to organise constructs in the new foreign language. Another explanation for irregular sentence construction is the emphasis that is placed on some aspect by the teacher or text book that causes the learner to over-use a construct. More interesting from the point of view of learner modelling are the strategies of learning and communication that are used to build new rules. Some strategies that the user may employ to simplify the task of learning are: over-generalisation where the learner applies a rule too widely; not knowing about restrictions on the use of rules; or incomplete application of a rule. Communication strategies are also important as a source of ungrammatical but understandable sentences. These are employed because the learner lacks the linguistic resources to express his intended meaning.

Although this deeper analysis of learners' behaviour is particularly beneficial in determining remediation strategies, since it identifies gaps in the acquisition process itself as well as the acquired knowledge, its disadvantage is that it is time consuming and suitable only for one-to-one tutoring. Thus it is an obvious candidate for computer-based teaching.

For an ITS there will be consequences for the process of building rules that account for stronger links between the learner's behaviour and its explanation[1]. This lead us to the concept of a structured applicable rule (Fig. 1). A central feature of the structure are the elements that represent the different explanations that can be given for the divergence of the grammar of the learner's sentence from some standard grammar. We talk about "divergent sentences" because the appreciation of the level of correctness will vary, depending on such conditions as: the state of the learner, the language objectives, and the context within which the sentence was produced. The explanations are expected to be of two forms grammatical and causal. The grammatical explanations describe in some meta-language, that the teacher thinks is appropriate to the particular type of learner, what the error is. The causal explanations will be along the lines of the basic misconceptions introduced in Error Analysis. Each separate description of a grammatical divergence will give rise to a separate applicable rule, but different descriptions of the same divergence will count as a single rule. The occurrence of multiple explanations also requires that the applicable rules can be related to one another and possibly to the computational grammar form of the rule or its standard counterpart.

Since there are likely to be several explanations of the same divergence some means of discriminating between them will be necessary. Teachers commonly use a dialogue containing examples and counter-examples as a method of differentiating between competing explanations of a learner's performance, hence this information must be gathered. How an applicable rule relates to a particular divergent sentence, and how it can be automatically selected as a possible candidate to explain the divergence is described by its computational code. Since applicable rules can be of very different sorts, procedures can be expressed in a computational linguistic formalism, or in a pedagogical grammar formalism or as meta-rules.
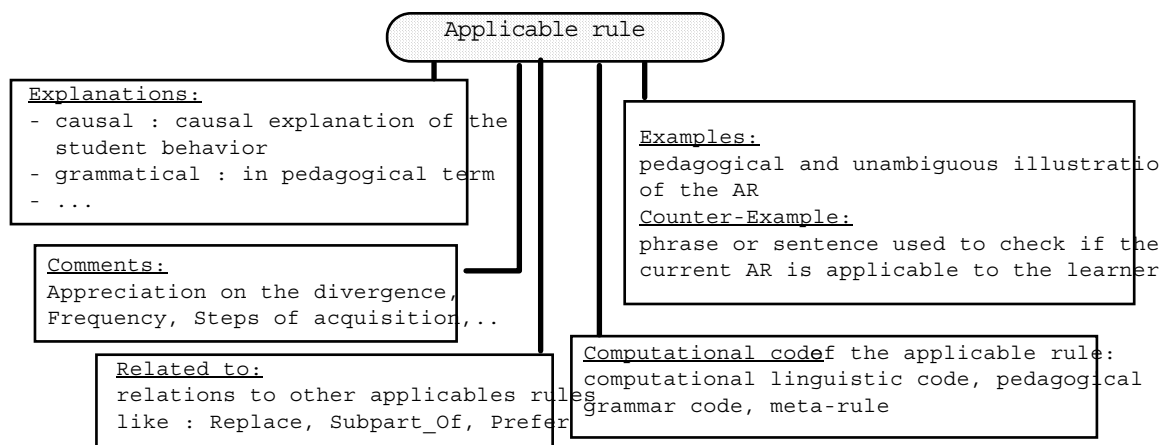

Figure 1: Structure of an applicable rule

3.   Interface for the Acquisition of Applicable Rules (IFAAR)

In order to acquire the information needed to fill the slots of the applicable rule structure, described above, we needed to develop knowledge acquisition techniques. The method that we chose was that of providing a structured interface and stimulating a dialogue with the user by means of concrete examples. That is we presented a sentence, that a learner had produced, to a user, normally an experienced teacher, and asked him or her to comment on it by entering

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[1] Different perspectives adopted by other ITSs on SLL and their limitations are presented in [3].

text into various windows of a computer interface that corresponded to elements of the applicable rule.

The principal features of the interface, called IFAAR, are illustrated in Fig. 2. The windows provide a loosely structured environment that reflects the uncertainty that there inevitably is in the first iteration of knowledge acquisition. By keeping the interface as flexible as possible we have attempted to encourage the users to provide their own interpretations of the kinds of information that they believe they use in diagnosing a learner's divergent performance but this has been at the cost of providing any automatic support.

Figure 2 General view of IFAAR window system

We have provided a focus for the expert by offering a selection of typical learners' divergent sentences for analysis. The sentences came from a problem solving exercise with a simulated system which encouraged English learners to produce interrogative sentences in French about family relationships. The windows labelled Divergent Sentence, Sentence Context, Parser Diagnosis, and Computational Error Rule provide the principal information that the analyst requires to make entries into the other windows, those that correspond to elements of the applicable rule framework. Supplementary information can be accessed by means of a "button menu" in the window labelled Linguistic Knowledge. This provides access to the parser with which examples may be checked. Windows associated with the applicable rule structure are opened via the Applicable Rule window. Data can be entered into these windows in any order. Multiple Explanation windows can be created for any one applicable rule. Relation entries were restricted in this version to hierarchical entries via the Parent Node box in the Applicable Rule window. The widow marked Computational Code would not be filled in by the teacher but by a computational linguist or the system designer, depending on the type of applicable rule created (see section 4). All window creation is by means of the mouse and buttons. All windows are scrollable and may be resized, moved and quit. A more detailed description of the use of this environment is given in [2].

4.   Experiments with IFAAR

Our experiments with IFAAR had two aims. The main one was to accumulate information about how experienced teachers diagnosed learner's performances during the learning of a foreign language. A subsidiary aim, which we will not develop here, was to refine the interface as a step towards making it an autonomous knowledge acquisition tool.

Although the system was designed for use by expert teachers we wanted to find out if advanced learners or new teachers could offer insights into how language is acquired that was radically different from the teachers' views. The interface provided an unsatisfactory means of doing this. Neither of the learners had sufficient knowledge of formal aspects of a language to be able to formulate descriptions of the observed behaviour nor were they able to articulate why they or others would produce the sentences. The value of having them use the system was that it introduced us to a potential method of aiding language acquisition; that of having a learner reflect on others' and their own mistakes within a structured environment. We also found that one of the novice teachers, whose approach to teaching language was communicative and whose major experience was with absolute beginners, was not capable of providing us with useful entries.

Different kinds of explanations

The explanations offered by the teachers of the learners' performances fell into three types corresponding to: why the performances occurred (causal explanation), what the performance was; and what performance would have been desirable. The last two types of explanation are grammatical ones, one corresponding to the learner's point of view as expressed by the user, the other one to the user's point of view on what is "correct". In order to avoid the confusion of defining at the same time and in the same place these two aspects, we think it is better to distinguish between *learner applicable rules* , which would characterise the learner's performance, and *teacher applicable rules* which would define what it should have been. The user could then define a relationship between a learner and a teacher AR. In fact, the set of teacher applicable rules correspond to a pedagogical grammar. The idea of having teacher ARs as well as learner ones also reflects a degree of equivalence between both agents, since the teacher may also be applying a subset of these rules to approximate the desired language competence as a pedagogic device to simplify the learning process.

There is evidence for there being two levels of causal explanation. One level of explanation suggests why the learner does not have the required rule, through forgetting or ignorance. In this case the diagnosis can be extracted from the learner's history. Causal explanations relating to this aspect were restricted by the limited data available in IFAAR. The other level of causal explanation suggests why the learner has acquired or generated the current applicable rule that produced the divergent performance. Explanations collected in the experimental data were those commonly presented in texts on SLL of language transfer, over-generalisation, simplification, etc. Hence it may emerge that a hierarchy of explanations can be constructed which may determine the method of remediation or future pedagogical strategies.

Meta-Language and pedagogical grammar

Grammatical explanations, were given at different levels of formality, the level of formality being dependent on the perceived audience. Hence the meta-language used to describe the rule was sometimes in the technical vocabulary of the linguist, at other times in a semi-formal language suitable for those with a developed knowledge of grammar, and sometimes in informal terms for those with little or no knowledge of grammar. At one extreme of this spectrum of descriptions could be placed the computational form of the applicable rule that,

we are now aware, must be generated by a computational linguist, and at the other extreme is an implied description of the performance provided by offering the learners sets of examples and counter-examples and allowing them to induce their own form of the rules.

We believe a consistent meta-language is necessary to provide grammatical explanations. This grammar in the BELLOC system represents the teacher's point of view on the linguistic knowledge which is to be learned. It cannot be the computational grammar (see the discussion in [3]), but it will need to be a formally defined *pedagogic grammar*, since, besides its description and implementation being indispensable for teaching purposes, it must function computationally to help in the diagnosis of the learner's divergences.

Roles played by the examples

Although the examples and reject examples collected could not in themselves provide guidance in any classification scheme, the verbal comments of the users suggest that they are used in at least three ways: to disambiguate competing explanations of a divergent performance, to refine an explanation, and as teaching devices (forcing the learners to build their applicable rules by induction).

Whatever role they play, it was emphasised by our expert teachers that examples play an important role in the pedagogical process. The reject examples can mainly be used as discriminatory examples between competing ARs. The positive examples can facilitate the learner's understanding of the grammatical explanations extracted from the ARs that BELLOC will use. Since examples must be linguistically and pedagogically relevant they need to be generated by hand by experts through IFAAR.

What kinds of applicable rules for IFAAR ?

From the experiments made with IFAAR and parallel investigations on ways to automate the generation of applicable rules, we have distinguished at least three kinds of applicable rules (more fully described in [3]):
  - *pedagogical grammar rules*: these correspond to the pedagogical grammar. They should be created by the designers of BELLOC.
  - *meta-rules*: some of them will operate on the pedagogical grammar rules in order to simulate, for example, the learner's processes of simplification and then generate automatically a learner's applicable rule. They should also be created by the designers.
  - *predefined rules*: they describe specific linguistic difficulties that only an expert teacher can predict. These rules are those which should be acquired through IFAAR.

5.   IFAAR as a teaching device

IFAAR could be used in its present state (or with minor changes and adaptations) as a teaching device, relevant either for the teacher or the learner.

For a given learner, the exercise of generating applicable rules from divergent sentences uttered by another learner can be a good way of imposing self reflection on his own system of rules. The reflection may come from the verbalisation of the rules, the examples produced, and from the different possible viewpoints on the given problem that will be achieved through generating, at the same time, one or several applicable rules accounting for what he guesses the other learner has done, and another applicable rule on what he thinks the remediation could be. In achieving this task, the learner will handle the language from different aspects: from a given sentence, he will give a translation, a remediation, examples and counter-examples, take the context into consideration, etc.

IFAAR may also be relevant for the teacher. The teacher's analysis of the results of the work done by his students in an IFAAR session can be useful to identify their grammatical competence. The evaluation of grammatical competence is an important matter in order to

meet the learner's needs [6]. But it is considered as being difficult to achieve through making judgements and corrections only on examples. It also requires tests to be undertaken in different situations: written, narrative, communicative,.etc. We hope that with IFAAR we will have almost all these requirements. This analysis may also give the teacher feedback on his teaching: when looking at the learners' rules, he may induce some relations with his own presentation of the rules. The expert teachers who have used the system told us that they found their situation interesting and quite unusual. In fact, a large part of what has been said about the learner could apply to the teacher as well. For an experienced teacher, or even more a trainee teacher, the use of IFAAR may bring useful reflection about how to teach rules, illustrate different perspectives, study the connection between their pedagogical grammar and the descriptive/computational grammar.

6. Conclusions

We have focussed on acquiring knowledge about the source of learners' language production rules as accounted for by expert teachers. We have proposed the uniform structure of an applicable rule into which this knowledge might fit. The window-based interface IFAAR, reflecting this structure, has been implemented and used in experiments with expert and novice teachers. From these experiments we have begun to validate the structure of an applicable rule and we also get a better view on how to automatically support the expert in the knowledge acquisition process. This may be useful for ITS in all domains [7]. In the future, this acquisition will mainly focus on a certain kind of applicable rules, we called "predefined," which encompass an expertise on the learner both indispensable in a computer-assisted language learning system and hardly automatically obtainable from any calculation. Finally, we pointed out how such environments for knowledge acquisition from experts could profitably be used as a means of teaching for learners or for trainee teachers.

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