A Constructionist Approach to Student Modelling: Tracing a Student's Constructions Through an Agent-based Tutoring Architecture

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Abstract. Construction Grammar (CxG) is a well-established linguistic theory that takes the notion of a construction as the basic unit of language. Yet, because the potential of this theory for language teaching or SLA has largely remained ignored, this paper demonstrates the benefits of adopting the CxG approach for modelling a student's linguistic knowledge and skills in a language tutoring application. I propose a tutoring architecture for (adult) second language learning that relies on a student model that tracks a student's constructional knowledge. This model is embodied in a fully operational student agent, which has a construction inventory, a grammar engine (to process constructions) and learning strategies (to update constructions after learning). Through linguistic interactions between a language learner and the tutoring system, the student agent is enabled to model the behavior of the real student and tries to predict his input. The student construction inventory is aligned to the real student's input after every interaction. This innovative architecture, implemented in Fluid Construction Grammar, is demonstrated here for the use case of Spanish past tense expressions, which remains a complex task even for the most advanced learners of Spanish.

Keywords: construction grammar, student modeling, agent-based tutoring system, Spanish past tense.

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1. Introduction

Learning a new language from a native speaker is usually more successful than learning from an L2 teacher who does not fully master the target language and knows little more than the phrases in study books. The same argument applies to computer-based language tutors: a good model of the target language should be flexible enough to understand and produce utterances that are beyond those found in exercises. Moreover, apart from modeling the expert speaker, a good tutor also keeps a model of the student that he is tutoring, to estimate his proficiency level and the difficulties that he encounters. Once a tutor has full control over these two models, he can apply a range of tutoring strategies to best guide the student through a set of exercises. Yet, the structure and implementation of the underlying expert and learner models needs to be flexible enough to allow tutoring strategies to do their work. This paper demonstrates the benefits of using a Construction Grammar (CxG) approach as the basis for the expert and student model and shows how constructions can be learned and adapted over time.

I have used the bi-directional construction-grammar framework Fluid Construction Grammar (Steels, 2011, 2012) to test this innovative architecture for the use case of Spanish verb conjugation, which remains a complex task even for the most advanced learners of Spanish. Through the use of carefully designed diagnostics and repairs, the student construction inventory can be updated to maximally approach the real student's linguistic knowledge of the target domain. This paper first explains the basic architecture of the CxG-based tutor in Section 2 and further discusses the first results of the use of a student agent for Spanish verb learning in Section 3.

2. Method

The CxG-based language tutoring system advocates the use of deep language processing and agent-based modeling to construct a language tutoring system for second language (L2) learners. It demonstrates the benefits of keeping an active and predictive student model that takes the form of an autonomous learning agent. The system consists of three main elements that are explored in this section:

- Because domain knowledge is a crucial prerequisite to construct a personalized language tutor it is necessary to have a fully operational **language agent** that can function as a competent language user.

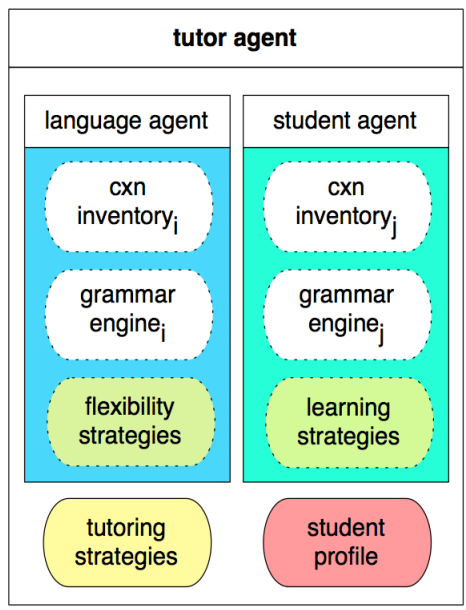
- A **predictive student model** in the form of a student agent with a structure that is identical to the language agent can be dynamically aligned to fit the real student's progress.

- A language agent can take up the role of the tutor if he is endowed with a set of **tutoring strategies**, which make use of the student model as well as a more general student profile module.

2.1. Language agent

The language agent that is presented here consists of three main components: a construction inventory, a grammar engine and a set of flexibility strategies (Figure 1). The first component, the construction inventory, is a catalogue of all the grammatical constructions that a language user typically uses. It can contain lexical constructions, phrasal constructions, morphological constructions, etc. that are each responsible for a small part in the processing of an utterance. The construction inventory can be organised according to different principles that are either driven by the implementation and processing perspective or by the psycholinguistic relevance of grammar organisation.

Figure 1. The language agent and the student agent share the same architecture; a full tutor agent that interacts with a student has three types of strategies that are distributed across its sub-agent components



The second main component is the grammar engine. This is the component that is responsible for the actual linguistic processing of the constructions that are collected in the construction inventory. This processing involves a search through the inventory to retrieve the constructions that are required to build or interpret a particular utterance. The grammar engine should allow for bi-directional processing so that the same constructions can be used in production and parsing. This bi-directionality is a crucial feature if we want to enable flexible processing, which implies that the tutor can try to reproduce the student's utterance to reconstruct the constructions that he accessed and the possible search path that was taken.

Finally, an expert language agent also has a set of flexibility strategies that allow for robust processing of the learner's utterances, especially when they contain mistakes. These strategies allow to always retrieve a solution when an erroneous utterance is parsed and to come up with a correction as well as the source of the error. A flexibility strategy contains diagnostics and repairs that identify the irregularity and find a solution to solve it. They are constantly active in a linguistic meta-layer that runs on top of regular processing so that they can catch every small deviation of regular construction processing (Beuls, van Trijp, & Wellens, 2012; Maes & Nardi, 1988).

2.2. Student agent

A good teacher naturally constructs a model of his student that represents the student's skills and knowledge as a function over time. It is a kind of model that could mimic typical student utterances that are illustrative of the student's proficiency level. In order to operationalize such a predictive model it is convenient to reuse the three-component language agent architecture. This student model is thus implemented as a fully-fledged agent, who can actively participate in the linguistic community that he finds himself in. This agent is also further referred to as a student agent.

Because the language agent's and the student agent's architectures are identical (Figure 1), it becomes very cost-efficient to construct a student model from scratch. The most important difference is, of course, the difference in competence level between the tutor and the student. The student does not yet master all the constructions that are needed to be fully expressive in the language that he or she is learning. Gradually, their construction inventory will expand and mold towards the target language. It might take different paths to construct an L2 language, so that different learning strategies are required.

Instead of flexibility strategies, a student agent has a set of learning strategies that are in charge of the continuous expansion and adaptation of the agent's constructions, which in turn is based on information that is gathered during processing. Learning strategies encode personal tactics on how to solve a particular problem and they can thus differ greatly between students. For instance, one learning strategy for learning Catalan would be to first conjugate all the verbs in their first person singular form. Another strategy would imply that you construct your sentences in Spanish (in case you master this language) and replace some of the words by their Catalan counterparts.

2.3. Tutoring strategies

Apart from making a dynamic model of the students, a human teacher typically also applies a range of tutoring strategies to assist students in their problem-solving tasks. A tutoring strategy is a dynamic plan of action that stipulates future interactions with the student. To create or adapt a tutoring strategy, a teacher does not only depend on the information that is kept in the student model but also makes use of a more general record of the student's strengths and challenges in learning.

The language tutoring system that is proposed here therefore hosts an artificial tutor that simulates these typical teacher tactics. As a result, the original language agent architecture needs to be extended so that this agent can also function as a tutor (Figure 1). Such a revision implies two new components as parts of a tutor agent, apart from having direct access to the student agent: a tutoring strategies component and a student profile component. These components are vital elements of a personalized tutoring approach because they provide meta-information about the tutoring process, for instance to decide which type of exercise to repeat or where to challenge the student further.

3. Results

The first case study with the CxG-based tutoring system focuses on the language system of Spanish tense, aspect and mood. After the development of a Spanish language agent with flexibility strategies needed to effortlessly parse erroneous sentences and correct them (Beuls, 2012), a student agent with learning strategies can be "cloned" cost efficiently with empty construction inventory and default grammar engine settings, completed with a set of learning strategies and designed for the target language system. A set of 10 diagnostics and 12 repairs is needed to fully operationalize the acquisition process of the Spanish verb system from contrastive situations such as "cantaba/cantía una canción", *he sang (perfective/*

imperfective) a song. First results have shown that the student agent learns more quickly and more efficiently when he can also speak and not only listen.

4. Conclusions

The architecture presented in this paper allows building a tutoring system for a specific subpart of a language for which the grammar engineer can develop all elements of the language agent. Once these elements are provided, the meta-level runs through all components of the tutoring system by means of flexibility, learning and tutoring strategies. The agent-based model of the real student tracks the performance of the student and has the capability to predict future utterances, which can in turn be used to select appropriate exercises for the skill level of the student.

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