Dialogue Systems for Language Learning

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Resumen: En este artículo se presenta el caso de Milao, un entorno virtual que ofrece a los estudiantes de idiomas extranjeros la oportunidad de desarrollar y mejorar sus habilidades comunicativas dialogando en escenarios de conversación predefinidos que simulan la interacción con un nativo. Esta tecnología propone una solución a uno de los mayores retos en el aprendizaje de lenguas extranjeras: la falta de oportunidades para poner en práctica la gramática y el vocabulario recién adquiridos. Combinando la investigación sobre la lingüística y el aprendizaje de lenguas con los avances tecnológicos en el campo del Procesamiento del Lenguaje Natural (NPL), particularmente sobre sistemas de diálogo, hemos creado oportunidades en la demanda de los estudiantes a conversar en la lengua que tratan de aprender.
Palabras clave: Sistemas de diálogo hablado, lenguaje natural, gestión del diálogo, aprendizaje de lenguas.

Abstract: This paper presents the case of Milao, a virtual environment that offers foreign language learners the opportunity to develop and constantly improve their communicative skills in a language they are trying to learn by participating in a set of predefined conversation scenarios that closely mimic real life situations. This technology proposes a solution to one of the major challenges in foreign language learning: the lack on opportunities to put into practice newly acquired grammar and vocabulary. By bridging linguistic and language learning research with cutting edge developments in the field of Natural Language Processing (NPL), especially Dialog Systems we have created on-demand opportunities for learners to *chat* in the language they are trying to learn.
Key words: Spoken dialogue systems, natural language, dialogue management, language learning.

1. Introduction

Learning a foreign language is a complex process that comes with many challenges. This paper will address one of these challenges in particular, that of becoming communicatively competent in a foreign language.

Regardless of the ongoing debates on the topic of language teaching and learning, most would agree that the aim of teaching and learning a foreign language is communicative competence (Canale and Swain 1980). That is, we should aid the learner in acquiring not only linguistic competence, knowledge of the grammar and lexicon, but also the ability to use language in real life settings to successfully communicate.

Before going into a discussion of how language is learned, it must be first established what learning a language actually entails. The underlying question from a linguistic perspective is '*what is language?*'

and secondly, '*what does it mean to learn a language?*' In an overly simplified definition, language is often referred to as a combination of grammar and vocabulary. So learning a language, be it first and second, is usually understood as the learning of a set of grammar and vocabulary rules. However, learning a foreign language is in many ways an even more challenging task than learning a native one. Just as when acquiring a first language, acquiring a second one entails almost simultaneous development of at least five basic levels. All of this, on top of the already acquired native linguistic system.

Learning a language implies developing a sound system, while at the same time acquiring syntax and morphology, understanding semantics and of course, pragmatics.

Minimal phonological knowledge implies that learners discover what sounds are even possible in a language. Moreover, the learner must understand how words change in fast speech as opposed to slower, more articulated speech. Morphological knowledge refers to the learners' ability to form words using different affixes as well as awareness of what affixes can do with what words. Syntactic knowledge is commonly known as grammar and often refers primarily to the order of elements in a sentence, which can be very different from one language to another. Most importantly, learners must learn *prescriptive grammar* (rules that are generally taught in school) as well as *descriptive grammar* (language as it is actually used). At the semantic level, learners must understand the meaning of words and what they refer to despite word limitations not always being clearly defined. Lastly, and this often comes with time and practice, is the knowledge of how language is used in context or pragmatics.

Evidently there is more to learning a language than just grammar and vocabulary. Furthermore, as related to foreign language learning, it is important to keep in mind that when learning a foreign language, it will interact with at least one pre-existing linguistic system, making the acquisition process even more challenging. Research on this topic has clearly showed that the developmental process at each of the levels described above will be influenced in great part by the learner's native language.

Subsequently, learning a foreign language can be in many ways, a more challenging task that developing a first one. Not only do foreign language learners have to learn how to deal with two co-existing linguistic systems, but they are also usually not easily exposed to the new language since it is not (in most cases) the language of the community they live in. Contact hours with the foreign language are reduced to a few hours a week and often the only contact with a native speaker is the teacher. Because classes are relatively large, there are few opportunities to use the language.

So then, how do learners work towards their ultimate goal of becoming communicatively competent?

2. Intelligent Tutoring Systems and Language Technologies

The idea of applying Artificial Intelligence to Education dates back to the early 70s, when the first implementations in the field known at that moment ICAI (Intelligent Computer-Aided Instruction) tried to build systems with the goal of improving instruction.

ITS (Intelligent Tutoring Systems) have been recently defined by Graessner et. al. (2005) as "computerized learning environments that incorporate computational models in the cognitive sciences, learning sciences, computational linguistics, artificial intelligence, mathematics, and other fields that develop intelligent systems that are well-specified computationally".

It is worth-noting the ample interdisciplinary background of this field, relying on the research and development in many scientific areas. Nevertheless, in spite of this challenge, the social and economical impact of this field are remarkable: an ongoing EU-funded project (I-TUTOR: Intelligent Tutoring for Lifelong Learning) has concentrated on the development of an ITS to be applied in online education to monitor, track, record behaviours, and to perform formative assessment and feedback loop

to students to foster a professional and reflective approach." [Paviotti et al 2012]

2.1. Natural Language as a Tool for Education

The learning process as a whole is often interactive in nature. Given this characteristic of learning, language technologies have the potential to play a crucial role as part of the design and implementation of different Intelligent Tutoring Systems (ITS). The biggest challenge when creating a tutoring system is to find a way that replicates the natural learning experience as closely as possible. Language technologies make it possible for the communication between the system (that will usually act as the teacher) and the student to closely imitate the natural learning environment.

Specifically, a training session should be analyzed as an open and dynamic conversation between at least the two mentioned agents (teacher and student), and the global design of the system must be thought as a natural language dialogue with a student incorporating the initiatives and expectations of both the student and the teacher, allowing at any moment new interactions from the student and the generation of responses from the virtual teacher in a natural way.

A first example of an ITS that relies heavily on language technologies is Why2-Atlas (Vanlehn 2002). The system is designed to teach qualitative physics making use of a complete Natural Language Processing (NLP) framework. The distinguishing characteristic of Why2-Atlas is that it divides the problem of understanding the user input in three main levels:

- The Sentence level: implemented by the SLU (Sentence Level Understanding module),
- The Discourse level (implemented by the DLU (Discourse Level Understanding module), and
- The Pedagogical level (implemented by the Tutorial Strategic Module).

A second example of an ITS is AutoTutor (Graessner et al., 2005). This tutoring system follows the explanation-based constructivist theories of learning. According to Graessner, "some of the recent electronic learning environments have moved beyond the conventional delivery of text, multimedia, and objective tests. There are systems with animated conversational agents, intelligent adaptive tutoring, interactive simulations, and other features designed to engage learners and promote deeper comprehension. One system is AutoTutor, a learning environment that tutors students by holding a conversation in natural language".

Overall AutoTutor stands as a valuable example of how language technologies can create engaging learning environments using strategies such as mixed initiative dialogue that guides the student in building an answer. Furthermore, it closely replicates the natural learning environment as it provides feedback to the student, prompts the student for more information, answers the student's questions, and summarizes answers.

The two systems provide concrete examples of how language technologies can enrich the learning experience for a variety of disciplines.

2.2. Natural Language as a Tool for Language Learning

In the sphere of language learning, applications of language technologies are not known to have been very successful. Although language learning has made use of some technological advancements, the language learning process has not yet been revolutionized by language technologies.

Overall, the application of technology to language learning has been done in a fairly conservative fashion. For example, many textbook publishers try to complement the poverty of interaction in the classroom with additional work on-line. However, in most cases what is produced is simply the same traditional exercises of a textbook delivered in a new package.

Another common area where technology meets language learning is known as machine assisted language learning. Matthews (1993) identifies a close relationship between Linguistic Theory, SLA Theory and the development of Human Language

Technologies (HLT) for Computer Assisted Language Learning (CALL). Gupta & Schultze (2010) point out that progress in HLT was made possible in great part by the insights drawn from linguistics and language acquisition research. Many of the advances in this field demonstrate how linguistic theories (phonology, morphology, syntax) can and should, in fact, be applied to the development of human language technologies and how these technologies can be further implemented in CALL software.

As far as the use of language technologies for learning a foreign language, one project worth mentioning is based out of Carnegie Mellon University and is known as the REAP project. Nonetheless, the scope of this project is quite limited as it specifically focuses on creating a vocabulary-learning tutor (Della Rosa and Eskenazi 2011, Heilman and Eskenazi 2006). The REAP project, despite some successes, it has faced and continues to face many challenges. Even when restricted to vocabulary learning alone, the challenges of applying language technologies to language learning are overwhelming.

Overall, when it comes to the application of language technologies to language learning, there is much room for innovation. This combination has not successfully been implemented thus far. The current paper presents the case of Milao, an approach that combines linguistic and computational motivation, incorporating a complete NLP engine and input and interaction linguistic theories.

3. Milao for Language Learning

Milao sits at a crossroad between Linguistics, Computer Science and Natural Language Processing. It is a product of knowledge gained through research in each of the fields involved. The Milao approach brings together second language acquisition theories such as input and interaction into a language-learning environment where learners become active participants in conversational exchanges that attempt to mimic real life situations. These conversations are made possible by the combination of technologies such as dialogue systems, the information state update approach and computational semantics.

In the field of second language acquisition, input is currently accepted as an essential factor in the process of learning a foreign language (Gass 1997). Research has clearly demonstrated that a language (first or second) cannot be learned in isolation and thus, exposure to input in a particular language is fundamental to the process of language development. To date, three main theories have addressed the role of input. Krashen's Input Hypothesis (Krashen 1981, 1985, 1988) was perhaps one of the first attempts at identifying the kind of input best suitable for second language acquisition. Specifically, it claims that comprehensible input (made available through context and speech simplifications) is the only kind of input that will lead to successful learning of a second language. Ideally, this input should be slightly above the learner's current level. The Interaction Hypothesis first proposed by Long (1981, 1983) coincides with the previous in that learners must comprehend messages in the input in order to successfully acquire them. However, this approach also claims that it is the interactional modifications that occur in negotiating meaning when a communication problem arises that leads to comprehension. That is, modified input that will lead to better understanding of meaning and consequently faster acquisition. A third approach, Swain's Output Hypothesis (1985, 1995) claims learner production (oral or written) is part of the process of second language learning and not merely its product. The learner must also have the opportunity to produce the language.

Computer Assisted Language Learning technologies have made great use of finding in the field of Second Language Acquisition and have successfully developed some language learning programs. These technologies are a great example of linguistic theory put into practice. There is no doubt that in order to successfully adopt technology into the language learning process, it must be closely based on such theories. Skeptics of Human Language Technologies however, argue that "Natural Language Processing (NLP) Programs cannot account for the full complexity of natural human languages" (Salaberry, 1996). These are all

acceptable arguments and the methodology proposed in this paper does not claim to fully replicate something as complex as human language in its entirety. With the help of human language technologies such as dialogue systems, the computer can now produce natural human-like interaction and thus provide the learner with the necessary input. Moreover, the use of speech recognition technology will allow the user to not only practice communication skills in the target language but also interact with the computer in a naturalistic manner, practicing complete phrases in realistic contexts.

NPL sits at a crossroads between linguistics and computer science, exploring the interaction between human language and computers. Currently, technologies developed in the field are used, among other things, in telephone interactions where the person needing information or help is speaking to a machine. The Milao approach proposes to adapt these technologies in order to offer students additional opportunities for practicing language. It recognizes that these interactions will not replace human contact, but they will however allow the student to experience some of the properties of one-on-one conversation. Moreover, it is the goal of Milao that these online interactions fill a real information gap, where the students make real contributions to the conversation by providing answers that are not previously known by their interlocutor. This information gap is often missing in classroom settings, where the teacher usually knows the answers to the questions he or she is asking, and is certainly missing in most current exercises developed by textbook publishers.

In the field of Artificial Intelligence, Natural Language Processing has concentrated on researching the foundations, methods and techniques related to the automatic manipulation of natural languages by means of computational platforms. More recently, this field has expanded to include multiple areas of knowledge and expertise, ranging from the linguistic study of the structure of languages, logical models of reasoning and their application to language modeling, psychological and neurological models of brain-related linguistic capabilities, computational techniques and models for the study and implementation of algorithms, cognitive sciences, among others.

Milao adopts these technologies to the field of foreign language learning in order to offer students much needed opportunities to develop and improve communicative competence. This of course implies the need of more powerful NL technology that is able to understand human language as a whole rather than only context-specific language.

The aforementioned limitations are among the main reasons why natural language technologies have not yet successfully been adopted in the area of second language learning. Another important reason is the poor communication between language technologies and linguistic research. Many scholars have pointed to the importance of linguistic theory (phonology, morphology, syntax) to the advances in the field of NLP and without a doubt, greater communication between the two will lead to even more significant developments in both fields. Milao has managed to overcome these challenges and create a methodology that will revolutionize the language learning space.

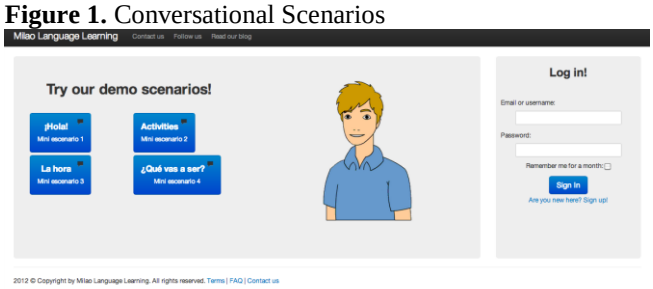
4. The Milao Technology

Our methodology will take into account two main constraints. On one hand, the achievement of the theoretical goals previously specified, mainly the specification of a system able to interact with a second language learners, covering a general-purpose lexicon as well as the main grammatical structures corresponding to the proficiency level. On the other hand, it must include the analysis of the dialogue strategies involved in the control of the interaction. From a methodological point of view, it is critical to differentiate between the native language of the learner, which we will call the Source Language, and the language being learned, which we will refer as the Target Language. In this project, we will concentrate on a global model for a Target Language (Spanish), using one Source Language (English).

a) Learning Scenarios and Linguistic Levels and Structures: The first step starts with the analysis of the interaction scenarios in the target language. As

part of this analysis we will provide a very detailed study of the basic vocabulary as well as the complementary lexicon related to the activities covered by the scenario. Additionally, this analysis will include the relation of grammatical models and patterns that must be taken into account for the corresponding learning level. The Milao platform allows the student to choose from a variety of conversational situations and engage in chats in the target language as outlined in Figure 1.

Figure 1. Conversational Scenarios



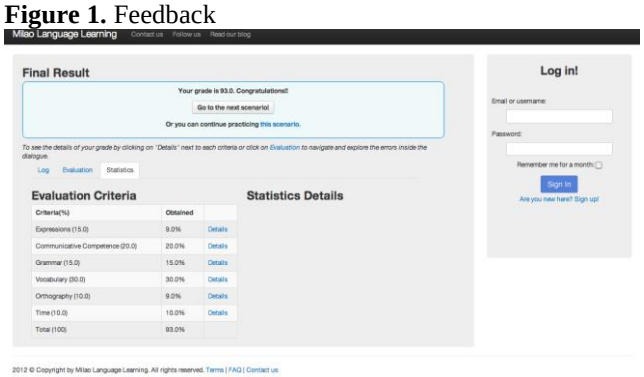
b) Interaction Dialogue Strategies: The goal of this task is to analyze, study and organize the interaction strategies that model and control the dialogue in the corresponding learning scenarios. It is important to attain balance between practical and theoretical motivation on this analysis, as we have to detect lexical and grammatical patterns in relation to the specific characteristics of the learner's Source Language. The strategies will be organized in three major categories:

- Domain-related Interaction Strategies: This group will include the models related to the scenario domain. For instance, for a traveling scenario, the strategies will organize the information related to time organization, destination, transport, and so on.

- Conversation-related Interaction Strategies: During the interaction, sometimes the learner will ask the system about clarifications, help sub-tasks, and so on

As outlined in Figure 2, the system provides a very detailed feedback on the learner's performance. Furthermore, analytics of this performance are generated in order to give a global overview of the learning process.

Figure 1. Feedback



4.1. The Role of Dialogue Systems in Milao

The key notion in the Milao approach for Language Learning is that of Language-Oriented Training Dialogue. A dialogue or a conversation can be described as a set of sentences between the virtual conversation partner (Milao's kernel) and the human learner. During the dialogue the learner and the virtual partner must collaborate to complete a conversation task. The main purpose of the dialogues is to give learners the opportunity to put vocabulary and grammatical concepts into meaningful utterances.

At a first level, the system (Milao's kernel) must be able to capture the input from the learner and analyze all the relevant linguistic information in order to detect linguistic mistakes, evaluate the performance and further guide the conversation.

The system analyzes the utterances at all levels of the language: morphology, syntax, semantics and pragmatics.

The Morphological Level

- The system analyzes the spelling, meaning and morphological features of words. For example, derivational morphology for nouns (genre, number), verbs (tense, person, …). In English, for example, the word "tables" is the plural form of the lexical item "table", which, on its side, must be linked to the corresponding meaning.

The Syntactic Level

- Combination of words following the syntactical rules of the corresponding language. For instance, in English "the big tree" is a correct phrase formed by a determiner, an adjective and a noun, while the same components in the sequence "tree the big" is not a grammatical one.

The Semantic Level

- The low-level meaning of the basic items, once integrated as phrases, creates new meanings. This compositional semantic mapping is again language-dependent and follows some rules the learner must know and master. For instance, in the sentence "the man ate the two apples" we must differentiate between an agent (the noun-phrase acting as the subject: "the man"), the action ("eat", in the 3rd person, singular of the simple past of the verb "to eat") and the object ("the two apples", in this case a noun phrase with a determiner, a numerical determiner and the noun ("apple") in plural.

The Pragmatic Level

- Sentences are linked to our daily-life communication in order to accomplish different types of tasks. Again, dialogues or conversations follow pragmatic conventions which are part of the language-learning process.

4.2. Main features of Milao at the Linguistic level

The application of Language Technologies to the specific field of Language Learning or Second Language Acquisition represents some critical challenges to the field of Natural Language Engineering. This section describes how Milao addresses some of these major challenges.

Morphological Level: the lexical module of the kernel focuses on the analysis of words. Milao can detect, analyze and link words as input items with the corresponding meanings. This task includes phenomena like:

- Word separation, in conjunction with the analysis of punctuation symbols, multi-token words (like "for instance", …)
- Miss-spelling detection and correction
- Multilingualism. A common phenomena amongst language learners is the confusion of words in different languages and/or the combination of phrases in their native language and the target language they are learning. For instance, if the reply to the question: "¿Qué edad tienes?" ("How old are you?"); the student replies: "Yo tengo veinte años old. Is that ok?". In order to maintain the conversation flow, the system splits the input into two main chunks: "Yo tengo veinte años old" and "Is that ok?". Milao detects that the first sentence was written in Spanish, although it contains a word in English ("old"), and that the second sentence has been written in English.

Syntactical Level: currently, many tools, systems and applications related to Natural Language Processing follow the statistical paradigm. Although the statistical models of language are quite relevant, they are not enough for the language-learning scenario. Our technical and linguistic strategy is based on a hybrid approach able to deal with rule-based (data or knowledge-oriented grammars) and statistically-based language models. In general, the grammatical level must be able to organize the input from the student (learner) as a set of minimal phrases (chunks) according to the linguistic model used as a reference. For instance, the analysis of a construction involving the use of conditional must take into account grammatical rules involving the structure (order), the tense of the verbs, an so on. As an example, if Milao's teaching agent asks the student at some moment: "Where would you travel if you were very rich?" and the student replies: "If I was rich then I travels by the moon". In this case, the grammatical model is able to detect that (1) the phrase "I was" is ungrammatical in the context of the conditional (if) structure, (2) "travels" is again incorrect, and (3) the expression "by the moon" is grammatically correct (as a prepositional phrase on its own), although it makes no sense in the context of the verb "travel". These features make Milao a

complete outstanding platform for Language Learning in comparison with many other Natural Language Processing tools and systems.

Semantic Level: even if a sequence of words can form a correct syntactic phrase, it must be analyzed from a semantic point of view in order to obtain the complete meaning of the utterance. Our approach is based on compositional semantic models, which in the end can recover, unify and build the abstract representation of the meaning of the phrases in the student's input. Following this paradigm, linguistic structures are connected to knowledge models, which in the end play a crucial role in language learning. Fundamentally, this approach allows the organization of items based on a set of shared properties. For instance, an item in the knowledge base like a person may have some properties like a name, a birth-date, a profession, a father and a mother, a set (possibly empty) of sisters and brothers and so on. On the other hand, actions (described by verbs) can connect items (objects in a general vision) and properties; for example, a sentence like: "My sister studies philosophy" can be semantically analyzed as correct, because it links a subject ("my sister") of human-type (and humans can study), and action ("to study") and an object ("philosophy").

By the same token, a sentence like "My tree studies philosophy" is lexically and syntactically valid, but is semantically ill-formed, as it tries to link the object "tree" with the action "to study".

Pragmatic Level: many existing instructional systems concentrate on the lexical, syntactical and partially semantic level. These systems usually ask the student a question, and accept the reply. Then, they compare the input and the expected reply and decide about the correctness. Obviously this is useful, but quite limited if we try to simulate a real teaching-learning scenario, where the process is based on the construction of very rich scenarios where the teacher and the student engage in complex conversations. Milao's goal is to reproduce this richer strategy. Dialogue modeling is a classical field of study, which connects research on computational linguistics, artificial intelligence and pragmatics. Milao's pragmatic approach is inspired by the Information State Update (ISU) paradigm designed in several European Union funded projects [Traum & Larsson 2003]. This feature represents a key point for its application to the field of language-learning. Basically, it allows the designer of the language curricula to represent the learning scenario as a task where the student must accomplish some results as part of the conversation. Additionally, Milao is able to memorize relevant information about the student's profile, so it can create a realistic learning scenario. The system will 'learn' from the student about their main characteristics, such as name, age, profession, favorite activities, and so on. This way, the system is able to build personalized dialogues.

4. Conclusions and Further Developments

The Milao approach brings together digital technologies, second language acquisition expertise and a highly developed dialogue system technology. This combination allowed for the development of an environment that will significantly enhance the communicative experience of second language learners. Milao is an innovative and sophisticated prototype that complements the learning of second languages in settings in which learners cannot have real immersion in the linguistic environment of the target language.

The Milao approach is unique and works well mainly because of its highly multidisciplinary approach. Working with experts in second language acquisition, the Milao platform pays close attention to factors that play a crucial role in the process of learning a foreign language and successfully incorporates them with the cutting edge technology. In other words, the Milao approach is not a technology designed for language learning, it is one that closely models the language learning process.

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