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Advanced Language Understanding and Dialogue Management for Language Learning

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Abstract
The current paper introduces an innovative technological framework named Milao. Milao is the result of multidisciplinary research that brings together a variety of different fields such as Artificial Intelligence, Language Technologies, Linguistics and Language Acquisition theories. The main purpose of this technology is to address the challenging task of achieving communicative competence in a foreign language. Despite the significant technological advancements in recent years, none of the existing tools have successfully addressed the language learning process. By taking a fully multidisciplinary approach, Milao had been successful in tackling some of the major challenges of human language. This paper describes the main methodological guidelines that stand behind the Milao platform.

1. Introduction: Context and Challenges
Language learning is a complex cognitive task, which involves many dimensions such as the student motivation, attitudes, individual factors, as well as access to effective language learning resources (teaching material, teacher's training, etc.). As a resource for language learning, the incorporation of progressively more sophisticated Information-oriented technologies have proven to play quite an important role in the language learning process. However, a truly effective adaptation to such technologies requires an interdisciplinary approach. Sophisticated technologies such as Artificial Intelligence and Language Technologies alone do not automatically translate into efficient language learning tools. Effective language learning technologies must be based on a deep understanding on linguistic and language acquisition theories. For this reason, a multidisciplinary approach that brings together cutting edge technologies and language research is the only way to creating a unique product.
As part of the Milao project we have explored the application of Advanced Language Understanding and Dialogue Management for Language Learning [1]. This paper describes the main challenges of this project, its global approach and the current development of the Milao Language Learning platform. We present the main methodological guidelines we are applying to the creation of the Milao platform. First, Language Learning must be modeled as a continuous and progressive task where the student is engaged in real-life conversational scenarios. Second, these scenarios must demonstrate linguistic flexibility unlike standard approaches where the scenarios are based on fixed and rigid scripts. Milao ensures this flexibility by implementing of a very innovative use of linguistic frameworks and artificial intelligence techniques, such as the use of the Information State Update to Dialogue Management [7]. Third, it is important that the scenarios adapt to the linguistic abilities and knowledge of the student, allowing a flexible and progressive learning process. Fourth, the linguistic level (based on Language Technologies) must connect at a very low-level with the ontological framework [8].
This set of methodological guidelines, globally considered, defines the main requirements and constraints of the Milao technological framework. Our main objective and challenge at the same time is to achieve a very realistic conversational scenario where the student is engaged in interactive tasks that mimic real-life situations. Section 2 of the paper concentrates on the incorporation of Advanced Language Understanding techniques. These techniques allow for a natural human-like interaction where the system understands and engages the learner into conversation just as a normal person would. It is crucial that this technology capture all the relevant information. It does so through a lexical and morphological analysis of the utterance, a syntactical analysis (expressions and structures), organization of meaning using an abstract representation and finally a pragmatic analysis of the carried information in the context of the dialogue as a whole. Section 3 describes the approach we follow for the creation and management of complex dialogue systems. The main ideas of Script, Phase and Task are presented. The link between the Language Understanding module and the Dialogue Management is provided by means of sophisticated semantic representations of the utterances

2 From Natural Language Processing to Advanced Language Understanding

The incorporation of Language Technologies in the broad field of Tutoring Systems [2] has mainly focused on the use of language as a communicative tool, where the tutoring systems have quite reduced linguistic capabilities: both the system and the student implicitly agree on the linguistic scope, and complex communicative phenomena such as ambiguity are ignored (usually as a side effect of the domain-oriented nature of the tutoring system) [3]. However, aside from the learning of grammar and vocabulary -which so far have been the focus of ICT [4] - language learning requires an advanced and detailed handle of the learners' linguistic abilities. Most importantly, as some previous projects have highlighted [5], language learning is a communicative and dynamic process and any technology applied to learning a foreign language must reflect these characteristics.

Our approach emphasizes the use of language in context through a progressively more complex set of learning scenarios where the student is involved in natural language-oriented dialogues. Consequently, the technical framework must integrate different technologies such as the use of Advanced Dialogue Management [6,7], knowledge modeling with Ontologies [8], and Natural Language Understanding and Generation.

Human language is perhaps the most complex informational appliance (in a broad sense). Its symbolic nature, in conjunction with its capability to connect the mind with the world and its intrinsic ambiguity make human language a completely unique device. Since it's beginning, Artificial Intelligence has pursued the implementation of different techniques to analyze and produce the different levels of the language. Although all human languages is are very complex systems, technological advances are consistently becoming more accurate in understanding and generating them.

Language learning however, imposes very specific and further constraints on the global trends of research and development in the fields related to Human Language Technologies. Basically, this area of application requires an in-depth and detailed analysis of all the information in the learner's utterance, including the errors s/he makes. By contrast to task-oriented dialogue systems or search engines where it is enough to capture the main points in the user's input, in language learning all the details must be integrated in order to provide comprehensive feedback to the learner. This is why the use of reduced schemata like keyword spotting or even the use of global context-free grammars has had limited benefits for language learning.

Milao's technological framework addresses this challenging task by incorporating highly Advanced Natural Language Understanding techniques. Although the final result provided to the student is pedagogically organized and structured, in order to provide a technically motivated vision of the model, we will divide its presentation in three main blocks:

2.1 Lexical and Morphological Analysis

The student's utterance or input must be analyzed at the level of words, tokens, punctuation and complex expressions.

The majority of tools for language learning lack a motivated and in-depth module dedicated to this task. However, this functionality is critical in the language learning environment both for written and spoken input. From the presence of oral mispronunciations or spelling mistakes to the simultaneous use of words of the native language, the lexical analysis of the input plays a crucial role.

The methodological framework of Milao includes a linguistic model able to represent all the expressions using a unified representation scheme based on the notion of LexicalItem. These lexical items can be words, but they also can represent punctuation symbols, numerical and multi-word expressions. Each lexical item includes all the relevant linguistic information (derived from the corresponding dictionary). Furthermore, in the case of misspelling, the lexical item includes both the produced form and the correct one. Additionally, in connection with the syntactic level described in the next section, the model can include virtual lexical items, that is, lexical items that should have been produced but they weren't. For instance, in the input sentence "I would like see the picture.", the lexical analysis will include a lexical item for the unrealized word "to" in the middle of "like see".

2.2 Syntactic and Semantic Analysis

This level concentrates on the creation of the grammatical structures that model and represent the student's utterances. We follow a chunk-based parsing system. The use of context-free grammars is useful to capture the regular nature of many human-language constructions. However, the reduction of the syntactic analysis to this linguistic level is completely inadequate. In general, the syntactic analysis is mediated and influenced by the semantic model.

In order to reflect this functionality and achieve a better grammatical performance, Milao's methodological framework incorporates the use of a linguistic model which integrates the use of high-level representation techniques for the modeling of the meaning, and quite efficient parsing techniques.
This level generates two main blocks of linguistic structures, parallel to the aforementioned Lexical Items. The SyncItem (list of syntactic items) reflects the chunk-oriented parsing approach. Each Syntactic Item comprises all the grammatical information of an expression, linking all the leave-nodes with the corresponding Lexical Items. This syntactic level can detect many linguistic errors or mistakes, such us the mentioned unrealized structures ("I would like see"), the presence of not required structures ("I would to see"), or even the use of wrong sequences of words ("I like would to see").
The SemItem (list of semantic item) comprises the end all the information from the different linguistic substructures (chunks). Additionally, this level can detect specific errors at the semantic level such as the use of invalid subcategorization models, or the incorrect use of semantic scopes.

3. Dialogue Management: Communicative Competence and Language in Use

The previous section has concentrated on the strategies for the analysis of isolated utterances. Nevertheless as many authors have pointed out, the main objective of learning a foreign language has always been communicative competence. One of the main strategies to achieve this objective is by giving learners the opportunity to engage into real-life dialog scenarios where s/he can practice his/her isolated grammar and vocabulary knowledge.
Milao's methodological framework aims to help language learners achieve their ultimate goal by incorporating sophisticated Dialogue Management techniques. Dialog systems have been used in multiple research projects and are currently a common ground model for industrial applications. Their capability to maintain a memory model of the conversation and the current state of the information model, allows the dialog manager to control the flow of information. Subsequently, they have been successfully applied to the implementation of Spoken Dialogue Systems for Task-oriented interactions.
But again, their use in the context of language learning imposes highly challanging constraints. Similarly to the requirements mentioned during the study of the Natural Language Understanding block, the dialog manager in the language learning scenario is not only oriented towards the achievement of a given task, but to the collaboration with the student, being able to detect and correct the student while interacting with the system.
Besides, the dialogues themselves should be as open and flexible as possible. Literature on preceding technologies using this approach in the language learning environment is in fact quite limited and even the few examples worth-mentioning usually follow a extremely rigid dialogue scheme.
By contrast, our methodological framework provides a reasonable flexibility, by the use of a three level organization schemata, as described in the next section.

3.1 Scenarios, Scripts, Phases and Tasks

In order to allow a natural conversational environment, the student is invited to interact in a given scenario with the purpose of completing one or a few specific conversational tasks (for instance, introducing him/herself to a colleague, booking a room in a hotel, etc.).
Internally, each scenario is modeled using a script, which comprises a sequence of phases. This structure captures the sequential nature of some human-to-human conversations (for instance, the greeting should be located at the beginning of the dialogue, while the leave-taking is the last phase). Each phase is modeled as a randomly triggered set of tasks. For instance, if the student is involved in the Introduction scenario, the main phase may integrate different tasks like providing the age, the city, the country and the occupation. But these tasks can be completed in a flexible order, and the student is not forced to follow and unnatural and unknown rigid order. Similarly during the conversation the system can also follow a random order.
Sometimes, this random nature is not completely flexible. For instance, if the system asks for the name (age, etc.) of one of the student's brothers or sisters, it should have prior knowledge of whether the learner has any siblings. Should the learner be an only child, this task can be modified to ask for the name of his/her best friend, for example. This feature is achieved incorporating dependency controls between tasks.
Additionally, as it is often the case at the beginner level especially, learners will often derail from the conversation stream and our system is flexible enough to allow it. This behavior is made possible by

the kernel of the system that incorporating a sophisticated mechanism, able to detect if a task is been triggered outside its phase scope. The system reacts following a human-like strategy.

3.2 Generation, Feedback and Evaluation

The output generated by the system, and provided to the student, also plays an important role in the whole conversational model. During each interaction, the system provides three levels of information. The main answer contains the direct reply, while the help answer provides hints that can be accessed by the student in case s/he doesn't understand what is supposed to do next. A third block contains examples that illustrate how to continue the conversation. The use of this additional information is stored by the dialog manager and impacts the final score. It is worth mentioning that all this information is adapted taking into account the proficiency level of the student.

Apart from the generated output, the system provides feedback to the student. This information is gathered from the four levels of analysis described (lexical and morphological, syntactical, semantic and pragmatic).

Finally, once the conversation for a given scenario is completed, the system provides a global evaluation of the learner's performance. This evaluation is organized in three main criteria: Intent (which reflects the attempt made by the learner to respond, the appropriateness of the response, the attempt to reply with an inquiry and its appropriateness), Accuracy (at the levels of vocabulary and grammar) and Fluency (taking into consideration the time it takes the learner to respond).

4. Conclusion

Milao takes on an extremely challenging task that has not successfully been done before. Our technology aims to turn Artificial Intelligence and Language Technologies into highly efficient language learning tools that will help learners develop and maintain their communicative skills in a foreign. However, despite the challenges, our results this far have been successful and encouraging to move forward. Further testing with language learners will allow us to improve and enhance the existing model. The Milao methodology stands as a great example of how multidisciplinary collaboration can lead to the creation of products that can be disruptive across disciplines. Not only does Milao set a precedent in the fields of Artificial Intelligence and Language Technologies, but is also highly likely to become a revolutionary methodology for language learning and teaching.

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