A software for language education and rehabilitation of autistic-like children

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Abstract

We present the EREL system, a therapeutic software for the education and the rehabilitation of children suffering from language disorders, especially devoted to "autistic-like" children. This system is based on the generic ILLICO software, a natural language system for analysing and synthesising sentences, and guiding if necessary their composition. ILLICO combines two principles: modularity in the representation of knowledge defined at the different levels of language processing, and sentence composition using partial synthesis and guided composition. We first describe the ILLICO system, and show how its two characteristics are relevant for the development of communication aids. Then we describe the functionality of the EREL system. Finally, we go into the details of an activity proposed by the software, and describe some specific elements of NLP required for its development.

1 Introduction

We describe here the EREL system, a therapeutic software devoted to the Education, Rehabilitation and Evaluation of Language devoted to children suffering from language (and then communication) disorders, and especially devoted to "autistic-like" children. In addition to their difficulties to express themselves verbally, many of these children suffer also from cognitive and/or motor disorders which make graphic or written expression difficult, and often make these persons keep socially apart (Ornitz, 1974) (Maurer and Damasio, 1982). But, given a motivating context, an individualised surrounding environment and materials, some of these children may be able to exteriorise capacities which had hitherto remained mute.
For more than ten years, a large amount of research has been carried out in the field of communication rehabilitation for handicapped persons, and technical aids known as "communication aids" have now been developed with some success. They can use "communication bords containing words (whose quantity, i.e. vocabulary, depends on the capacities of the user), graphic representations (pictures and photos, hierarchies of pictures, e.g. TEACCH program widely used in USA), written communication, synthetic voices. They aim to compensate the loss of communication for people without the use of speech. The use of computers as an intermediary has been seen as a natural extension of the use of classical communication aids; it may enable to bypass the different handicaps temporarily at least, and to compensate for the problems with language and motricity (Garoux et al. , 1989) (Howlin, 1989).

The EREL system, described here, is an application of research in the domain of natural language processing and especially of the development of natural language interfaces, and has been designed in a collaboration with medical staffs (doctors, psychologists, etc.) specialised in the treatment of children suffering from developmental disorders (such as typical and atypical autism, or childhood psychosis) (Godbert, 1996). The system provides a set of educational play activities illustrated through multimedia technology and designed to stimulate and help users to employ common language to express themselves within a specific context.
The development of EREL is based on the French ILLICO system, a generator for various natural language processing systems which provides a set of language processing tools using computational linguistic techniques making it possible to produce text in a "guided mode" (Pasero and Sabatier, 1994) (Pasero

and Sabatier, 1997). We will show that this mode is of great relevance to communication aids for the disabled.
In part 2, we describe the ILLICO system. In part 3, we mention the state of the art in the domain of communication aids for autistic children, and we show why ILLICO is relevant to the development of software devoted to the rehabilitation of persons suffering from language disorders. The functionality of EREL is described in part 4. Part 5 goes into all the details of an activity proposed by the software, and describes some specific elements of NLP required for its development.

2 The ILLICO system

The ILLICO system is a generic system for natural language processing (NLP). It provides a set of NLP tools making it possible to develop various applications, such as intelligent natural language interfaces for databases, communication aid systems, computer assisted teaching or learning systems, etc. ILLICO has been designed from the following two principles:

1. Modularity in the representation of knowledge defined at the different levels of language processing (lexical, syntactic, semantic, conceptual, contextual levels);

2. Sentence composition using partial synthesis and guided composition.

Modularity in knowledge representation

The different types of linguistic knowledge are independently encoded in separate modules; this ensures their portability, and makes easier their updates and interactions:

- a lexicon contains expected words and expressions;

- a grammar specifies the expected sentence structures and the grammatical agreement;

- a set of semantic composition rules produce semantic representations from the syntactic rules of the grammar;

- a conceptual model specifies, in terms of relations, the world of the application;

- a contextual model specifies the objects introduced in the preceding sentences.

Guided composition of sentences

The kernel of the ILLICO system carries out an interactive processing of natural language, based on partial synthesis, which checks the well-formedness of the produced sentences as the user goes on composing the sentences. This checking is simultaneously done at all the levels of well-formedness: the constraints defined at the different levels are coroutined (i.e. taken into account in a "parallel-like" way), in an algorithm which runs either in parsing or in synthesis.
Sentence composition using partial synthesis enables the system to offer the possibility to generate sentences in a "guided mode". In this mode, the user is guided while he produces text: at each step of the composition of a sentence, the system synthesises and displays the words and expressions that can be used to continue the sentence and that will lead to a well-formed sentence. The guided composition mode enables the development of user-friendly interfaces in which errors on the domain of the application never occur, and in which non-expected (i.e. incorrect) expressions are never used (Pasero and Sabatier, 1997) (Pasero and Sabatier, 1994) (Milhaud, 1994) (Godbert et al. , 1993).

3 Using ILLICO for a rehabilitation system

What is the state of the art in the domain of AAC for autistic persons ?

We have carried out a survey in the field of currently available communication aids for autistic persons, to try to determine the qualities and shortcomings of these systems. In fact, the international state of the art in this domain is rather poor. We can mention "Speaking Dynamically", "Boardmaker" (Mayer-Johnson, USA) as well as "Talk:About" (Don Johnston, USA). These systems use boards and picture communication symbols to compose picture sentences, some of them use a set of predefined sentences. We must also mention the "Facilitated Communication" method, which aims to help the user to use a keyboard of a computer to express himself by words and sentences. But Facilitated Communication is devoted to persons who are physically unable to communicate, but do not have a difficulty with communication at the cognitive level. We must also note that ordinary computer assisted language learning systems can seldom be used by autistic persons for they require intuitive cognitive knowledge which is often lacking in autistic persons.

Why is ILLICO relevant to the development of a language rehabilitation software ?

First of all, we think that the two characteristics of ILLICO described in part 2 are big assets for the development of a language rehabilitation software:

• In the guided mode, the user is led step by step during the construction of each sentence. This allows him to compose rapidly, with minimal cognitive load, sentences which are always correct at each level; this ensures also that the system never jams, i.e always "understand" what the user says. So the user doesn't become discouraged by fruitless attemps. The guided mode allows to begin rehabilitation as soon as possible, even for very young or seriously disabled children.

• The modularity of ILLICO is also a great asset, because it makes it easy to define various exercises about language with different levels of difficulty: by using linguistic modules (lexicon and grammar) with broad or restricted coverage, by allowing or not the guided mode, we obtain a lot of different exercises, among which one can choose the one which is suitable for each user's capacities.

• Moreover, the ILLICO system, through the modularity of its knowledge bases (defined at every level of well-formedness), makes it possible to propose different steps in the language acquisition or rehabilitation process:

- a *lexical* step which proposes exercises that allow acquisition of words and expressions of language in agreement with the subjects proposed;

- a *syntactical* step which allows the acquisition of grammar rules by controlling the syntactic correctness of sentences;

- a *conceptual* step which allows the user to acquire common sense rules by controlling the semantic correctness of sentences;

- a *contextual* step which makes it possible for the user to learn how to link sentences with the "real" world; at this step, the system verifies that the sentences make reference to objects actually present in the world; this arises in particular when using pronominal references or definite descriptions.

From the survey we have made of the existing software in AAC, we are convinced that the sound techniques from artificial intelligence and computational linguistics provided by the ILLICO system are very interesting and innovative in the field of communication aids for autistic persons: in the elaboration of our language rehabilitation software described below, our method has consisted in adapting existing technical solutions (graphic interfaces, etc.) to the needs of autistic users, by integrating ILLICO's technology. We believe that the language systematic interactions (between lexicon, syntax and semantics) carried out by ILLICO are crucial for the treatment of language and cognitive disorders, i.e. can help users to improve their language and cognitive skills. In what follows, we first describe the functionality of our EREL system, then we detail one of the activities proposed, and describe some specific elements of NLP required for its development.

4 Functional description of EREL

The EREL system provides a set of user-friendly educational play activities (logic games or scenarios), designed from communication and language training and learning exercises, and designed to stimulate, encourage, and help users to employ common language to build up an everyday language dialogue in interaction with the system, within a modular and multimedia context. Generally speaking, users will be able to express themselves on the subject proposed by the activity, with the assistance of the system (guided composition of sentences) or freely (free composition). The software has been designed as a multi-level and multi-user system: a system flexible enough to be adapted and to respond to specific needs according to the user's skills, which depend on his level of language and cognitive development, and his degree of autonomy.

The set of activities proposed by EREL

The activities to be chosen are dialogues on scenarios or on logic games:

• In the first case, a scenario is illustrated by a picture or a photograph; the user comments on with sentences describing what he sees on the screen. Pictures are a medium for language, and allow a child to enter a world by playing. The objective of this kind of activity is to incite the user to build simple sentences on a theme, and to develop the child's ability for naming, categorising or generalising an idea.

• The second activity concerns dialogues on logic games based on pictures or puzzle pieces. Users play by means of sentences: on one hand, they may compose orders to achieve a goal (for example to move a piece of a puzzle), or they may comment on the progress of the game. The aim of this activity is the verbalisation of the action. The idea is to encourage the children to use language for doing tasks composing a logical sequence of actions.

These various activities are especially designed to help medical staffs in the evaluation and the rehabilitation of the users' abilities to:

- Associate a word with a picture, generalise a concept, an idea,

- Work on space locating and logical constructions, illustrated by pictures and by the movement of puzzle pieces on the screen according to the actions expressed by the users.

All this work is carried through a common language dialogue.

Various working modes

The EREL system has a modular architecture, which allows to select the linguistic complexity of the activity, for a gradual work: each activity uses, among a set of available grammars and lexicons of gradual complexity, those from which the sentences will be constructed. It is therefore possible to use the system for the education of children with different levels of development, attention or reading skills. Besides, for each activity, the system proposes a set of functionalities responding to different requirements and competence levels, in accordance with the work that is expected to be done by the user. The working modes can be:

- Discover linguistic components (the lexicon, the conceptual model, etc.), to enable users to familiarise themselves with words and concepts.

- Produce text related to the scenario or game components.

- Study the logical representation of the sentences' semantics: for some of the proposed activities, the system provides a graphic representation of the semantics of the resulting sentences (i.e. their underlying meaning), using a simple and logical graphic formalism. In the opinion of the doctors we have consulted about this project, this access to a semantic representation of the sentences is extremely interesting with regard to the treatment of cognitive disorders.

The operating modes and interfaces

The input/output devices are defined to respond to the users' needs to the best, and to optimise their interactions with the system. In the guided mode, the software is operated by means of a series of graphics selections on the screen. The system can be used with or without an assistant, depending on the user's autonomy. Besides, the software is a real multimedia system, each activity being illustrated through several coordinated methods: writing sentences on the screen and synthesising them orally, graphic representation on the screen. This multimedia nature of the software means that the different media are coordinated and organised in a coherent way, and this seems to be a crucial point for persons with language, cognitive and motor disorders.

5 Example: an exercise proposed by EREL

Presentation

One of the exercises proposed by the software consists in putting and moving objects on a board. A child has a stock of objects that he can put on a checker board, permute, move or stow away. He gives orders to the system using natural language sentences and he can see immediately on the board the effects the sentences have. In addition to the linguistic learning, this type of exercise makes it also possible for the child to develop his capacity to locate himself in the space. The interface looks like this:

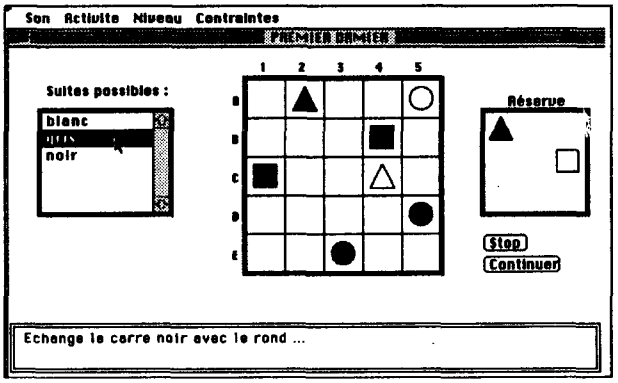

Figure 1: Example of a logic game in EREL

Here, in the French version, the user has begun a sentence *Echange le carré noir avec le rond...* (*Permute the black square with the circle...*) and the system, according to the contextual situation, proposes the possible words to be selected: *blanc*, *gris*, *noir* (*white*, *grey*, *black*).

Here are some examples of sentences corresponding to different levels of difficulty:

- *Permute the grey circle with the black triangle.*
- *Put the white circle in the square A5.*
- *Put the white triangle under the pawn which is in the square B4.*
- *Put the grey triangle at the left of the pawn which is situated under the pawn which is ...*

The different levels that we have defined correspond to levels of difficulty lying in the linguistic forms proposed (broader and broader coverage and finer and finer sentences decomposition in the guided mode) and, in parallel, to an extension of the cognitive possibilities (in particular, in space locating).

Concerning linguistic forms, the system proposes, for example, graduated ways to designate objects:

- At the simplest level, an object is necessarily designated by its shape and its color (*the black circle*) and plurals are not allowed.
- At higher levels of difficulty, the use of relative clauses is allowed and an object can be designated by its position (*the circle which is in the square A3*); plurals (*the circles*) and the generic word *pawn* are also allowed.
- Finally, the use of pronouns (in particular, clitic pronouns like in *put them in the square A3*) makes it possible to designate objects referentially.

Concerning space locating, several levels are also possible to point out a square or a position.

- A first level proposes to point out a square simply by clicking on it; then, the system completes the sentence of the user with a noun phrase corresponding to the expression of the position designated that way.
- At higher levels, a square can be identified by its position on the checker board or by its content (*the square which contains the black round*). At first, the positions are absolute (*the square A4*), then relative (*at the left of the square A4, above ...*).

Concerning composition within the guided mode, we have defined two levels: a first one, where the whole syntagms are not decomposed and are considered as final expressions of the grammar, and a second one where the decomposition is made at the level of the words. In the first case, the child has to choose first of all a verb (*put*), then, if necessary, a whole noun phrase (*the black triangle*), and then, if necessary, another whole noun phrase (*in the stock*). This mode is only possible in the case where the linguistic coverage is reduced (no relative, for example) and it is very useful for the child to discover the abilities of the system.

Some technical points

The linguistic levels proposed in this exercise do not create any problem as for the linguistic surface forms which are very simple.

A grammar has been developed which describes the highest level of difficulty. In order to compute lower levels of grammars, some rules of this grammar can be dynamically switched off according to the value of a global variable coding the level chosen by the user. A lexicon and a set of semantic composition rules have been developed and are used in the same way.

The conceptual model describes the world of the application in terms of domains of objects and possible relations between them. In order to take into account spatial expressions like *above the square B4* or *at the left of the pawn which...*, we have specified which objects can be categorised as a place and which ones cannot. Following (LePesant, 1996), we think that not all the words which can appear in spatial expressions are places, but only some of them like *square, stock*. This allows us to distinguish between the correct spatial expression *in the stock* and the incorrect (according to our application) one **in the triangle*. In order to describe the conceptual features of correct expressions like *above the triangle*, we consider this sort of prepositions as functions which, applied to an object which is not a place, give a place as result: thus, the expression *above the triangle* can be used with a verb like *put* which requires a place as a complement (*put the grey circle above the triangle*).

Some forms need a more elaborated semantic processing and, in particular, definite descriptions like *the black circle, the pawn which is at the left of the square which contains the black triangle*. Following (Russel, 1905) and (Strawson, 1950), we consider that a definite description refers to one and only one object in the context. In the type of applications described here, the object so designated must be identified by the system in order to act on it and the consequences of the action upon the object must be taken into account in the representation of this object in the context. All these operations are made by the contextual module. Moreover, as we exposed in (Mouret and Rolbert, 1996), the treatment of definite descriptions when used in the guided mode, introduces particular constraints: because the system must propose correct sentences only (and beginning of correct sentences only), it has to know as early as possible (and actually in advance) which definite descriptions are correct according to a particular context. These constraints require the system to apply specific processes to the context in order to know which objects can be designated by a definite description and which cannot: if there is no such objects in the context, then no definite description can be produced. If such objects exist in the context, the system can produce definite descriptions which must agree with the description of these objects.

Finally, the actions underlying the sentences have to be computed; their treatment introduces the general problem of the "semantics of actions".

6 Conclusion

In this paper, we have presented EREL, a language education and rehabilitation system for autistic children, developed from the generic ILLICO system. This software fully uses the natural language processing techniques provided by ILLICO, and in particular the principles of modularity and guided composition. We have shown why guided composition is especially relevant to the development of communication aids, and how the use of ILLICO makes it possible to develop software which can help users to improve their language and cognitive skills. More particularly, we have detailed through an example how the modularity of ILLICO allows us to define several language rehabilitation exercises which have different levels of difficulty from a linguistic and cognitive point of view. The development phase of EREL has shown that the particularities underlying this type of applications can easily be incorporated inside ILLICO.

The system is intented to be evaluated through the clinical and cognitive evolution of the children, first by medical personnel who will use standard evaluation methods, and also by the families, who will be able to daily test the appropriateness of the system for their children. Until now, it has not been possible to carry out a several months evaluation of the expected therapeutic effects on the population: presently, a medical team just begins to use a prototype of the system with autistic-like and psychotic children.

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