A Dialogue-Based Architecture for Computer Aided Language Learning

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Abstract

In this article, we propose a dialogue-based architecture for foreign language learning in the context of an engaging activity (the simulation of French cooking). Our approach consists in rejecting the "classic" linguistic evaluations (such as multiple choice questionnaires) in order to implement a *communicative approach* to language learning. A Wizard of Oz study reveals this approach is promising. The system is not implemented yet, but its architecture is based on several implemented systems, in particular on a dialogue model we have developed within the framework of other projects concerning Human-Computer Dialogue.

Introduction

Developing tutorial dialogue systems requires to be experienced in both Human-Computer Dialogue (HCD) and Intelligent Tutoring Systems (ITS) but we very often tackle these kind of projects through HCD or through ITS. The architecture we propose is mainly based on previous works on HCD [Lehuen & al. 96], [Lehuen 97], [Luzzati 00] but includes works on Computer Aided Language Learning (CALL) [Pilkington & Parker-Jones 96], [Boylan & Micarelli 98], [Katz 99]. Our objective is to build a system to learn French (as a foreign language) by implementing a communicative approach to language learning. Its aim is twofold: to provide a communicative learning activity and to build a learner model by observing the dialogues between the learner and the system. In this paper, we progressively describe the architecture of the system. Some parts of this architecture, like the "Linguistic and Pedagogical Observer" are not described because they will be designed when the dialogue subsystem is completely designed and operational. Finally, we describe a prototype of such a system and we mention a "Wizard of Oz" study carried out with this prototype.

Considering that *language learning is experiential* [Swartz 92], we have decided to reject the "classic" linguistic evaluations, such as the multiple choice questionnaires or the counting of grammatical mistakes, *etc*. These activities are not, in our opinion, significant measures of a learner's communicative ability. In a communicative approach, learning a foreign language means acquiring a formal/grammatical discourse, referential and strategic competencies as well as a sociolinguistic experience [Chanier 94]. This means that we consider language not as a static set of grammatical rules anymore, but as a dynamic process, as a communicative tool. Consequently, if we want to gather relevant information about the learner's language ability, we must do it through an authentic context because *with an artificial context, the data and conclusions drawn from it may just be methodological artefacts* [Hamburger 94].

Taking into account these requirements, we propose to simulate French cooking. It is a cultural immersion: indeed, cooking is one of the essential cultural elements in France. It also presents the advantage of being common to the daily universe of occidental people (the kitchen). We propose two conversational modes: first, the system leads the dialogue and it has to make the learner do the recipe (the learner practices his/her comprehension); later, the learner leads the dialogue and he/she has to make the system do the recipe (the learner practices expression) thus, he/she shows if he/she has internalized the activity and especially the language or not. In these two modes, dialogue is the central issue (fig. 1). All the architecture depends on this aspect.

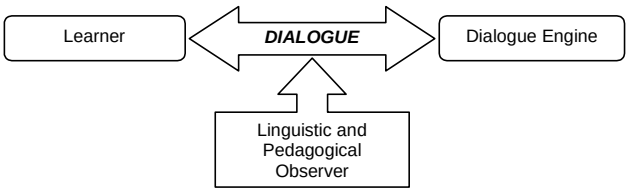

Figure 1: Dialogue as the central issue in a language learning context

The following dialogues (adapted and translated from our "Wizard of Oz" corpus) are based on these two conversational modes. These dialogues will be used as examples throughout this article.

System	"Please make a chocolate cake"
Learner	"How can I make it?"
System	"You take a bowl"
Learner	[action on the bowl]
System	"Well done. Now, you take flour"
Learner	[action on the flour]
System	"Ok. Do you have an idea of what is to be done with the flour?"
Learner	"Yes"
System	"Please tell me"
Learner	"Poor in the bowl"
System	"It is necessary to control the quantity"
Learner	"Control?"
System	"Well, it is simple: take the measuring jug"
Learner	[action on the measuring jug]
System	"You must put 250g of flour in the measuring jug"
Learner	[…]

Dialogue 1: Comprehension mode (the system is the leader)

System	"How can I make a chocolate cake?"	S2 (1)
Learner	"Take the bol"	L1 (1)
System	"What do I have to take?"	S2 (2)
Learner	"The bol"	L1 (2)
System	"You want me to take the bowl?"	S2 (3)
Learner	"Yes"	L1 (3)
System	"Well done. Go on…"	S2 (4)
Learner	"The flour"	L1 (4)
System	"What do I do with the flour?"	S2 (5)
Learner	"Poor the flour"	L1 (5)
System	"Poor the flour where?"	S2 (6)
Learner	"In the bowl"	L1 (6)
System	"Well done. Go on…"	S2 (7)
Learner	[…]	

Dialogue 2: Expression mode (the learner is the leader)

Model of the Dialogue

We have built our architecture around a dialogue model we developed within the framework of another project concerning HCD and Machine Learning [Lehuen & al. 96], [Lehuen 97]. In these works, we prove it is possible to improve the linguistic knowledge of a system during its interactions with users. We have decided to re-use and adapt this model within the framework of this new project. This section describes the generic aspects of our dialogue model: a single interactional component and two structuring diagrams.

Minimal Units of Interaction

We are now going to introduce the concept of Minimal Unit of Interaction (MUI) which determines the other elements of the model. The MUIs are adjacent pairs [Schegloff & Sacks 73] containing a set of information related to an utterance of the system and to the answer of its interlocutor. The MUIs enable the system not only to delimit a significant segment of interaction, but also to circumscribe a pragmatic context for the interpretation of the interlocutor's utterances and for the reaction of the system. When the system dialogues, it builds a recursive structure which contains MUIs in real time.

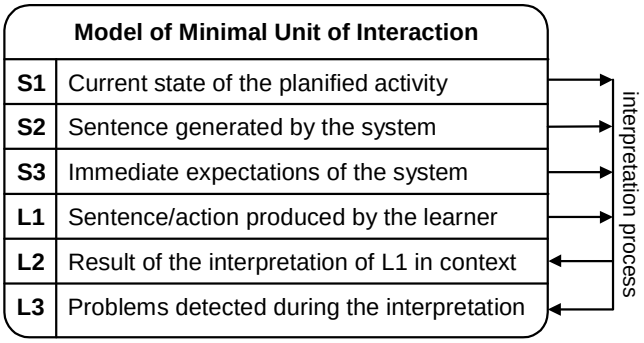

Figure 2: Model of a Minimal Unit of Interaction

Each new MUI is initialized with the three following fields [S1, S2, S3]. The S1 field points to the current state of the activity. It refers to the activity which can be dynamically planned or preplanned (see section 3 for details about the activity's model). The S2 field contains the sentence generated by the system according to the dialogue context. The S3 field contains the immediate expectations of the system. These expectations are a set of speech acts [Austin 62], [Searle 69], linguistic items (see section 4 for details about the linguistic model), or a non linguistic action (see section 5 for details about the interface). They define the immediate context for the interpretation of the learner's utterance. The three following fields [L1, L2, L3] are filled after the learner produced a linguistic or non linguistic action which is coded in L1. Then the system calls upon a series of linguistic tools to produce understanding structures. Finally, the system tries to interpret L1 according to S1+S2+S3 (the context for interpretation) and puts the result of its interpretation in L2. The L3 field will contain problems detected during the interpretation process. Figure 3 shows the complete MUI n°1 for the dialogue n°2.

Minimal Unit of Interaction n°1 (dialogue 2)	
S1 (1)	Task: To make a chocolate cake (see fig. 8)
S2 (1)	*"How can I make a chocolate cake?"*
S3 (1)	Directive speech act
L1 (1)	*"Take the bol"*
L2 (1)	To take A1 ; A1 = the bol (see fig. 11)
L3 (1)	Unknown lexical entry: *"bol"*

Figure 3: Example of a Minimal Unit of Interaction

The reaction of the system depends on the learner's utterance. If the system detects serious linguistic errors in the

answer, it can introduce a reformulation or a correction of L1, but this is not systematic: it depends on the objectives of the session. If the system cannot understand the answer, it can introduce an interactive interpretation which consists in negotiating the interpretation of L1. In all these cases, the dialogue is structured in a particular way.

Structuring diagrams

At this point, we're going to describe the two structuring diagrams: the *managing diagram* and the *incidental diagram*. These diagrams orient the dialogue in two different axes: an *activity axis* which denotes the progression of the activity, and a *metalinguistic axis* which represents the resolution of language phenomena [Luzzati 95 and 00]. If no problem appears during the interaction (the learner's utterance can be interpreted without requiring any reformulation nor further information), the system implements the managing diagram, the interaction then continues along on the managing axis (fig. 4). On the contrary, if the system fails in interpreting the utterance or detects serious linguistic errors, it implements the incidental diagram to recover the failure, or introduces an explicative or metalinguistic sub-dialogue (arrow n°1). This sub-dialogue corresponds to a block of MUIs delimited by an *incidental container*. As soon as this sub-dialogue is finished, the problematic MUI is reevaluated (arrow n°3) and the interrupted dialogue can continue on the activity axis (arrow n°4).

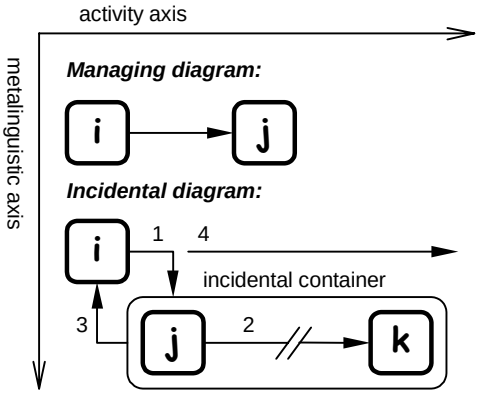

Figure 4: Simple structuring diagrams

The incidental diagram is applicable to any MUI, whatever its depth of embedding in the structure. The incidental diagrams can follow one another or be embedded in one another (fig. 5). This is why the model is able to produce complex recursive structures. Figure n°6 shows a complex structure which corresponds to dialogue n°2. It contains seven MUIs, three managing diagrams and three incidental diagrams. This structure is not hierarchic, like the structures produced by Roulet's model of dialogue [Roulet & al. 85], but recursive and linear (we can follow the making of the structure).

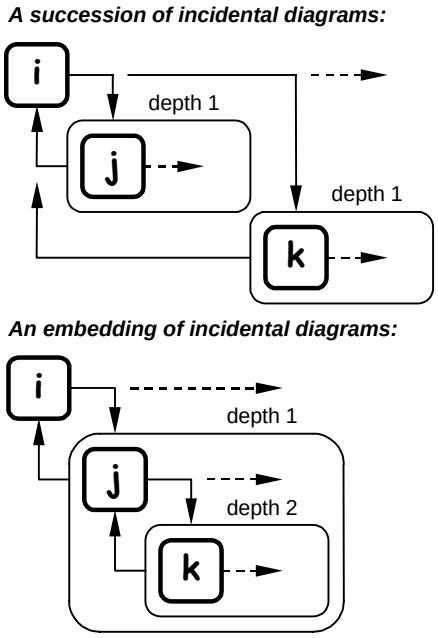

Figure 5: Complex structuring diagrams

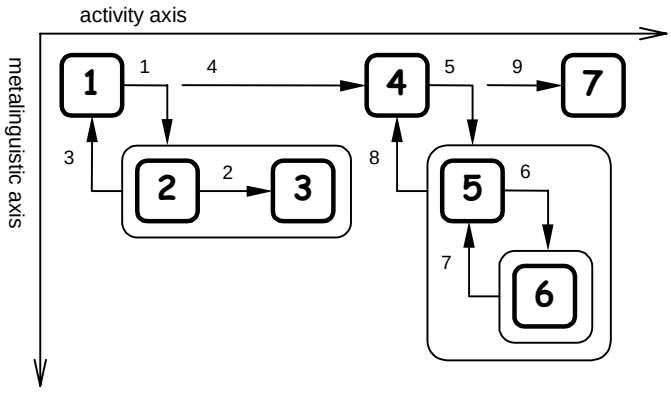

Figure 6 : Structure of dialogue n°2

Evaluation of the communicative ability

The structuring of the dialogue according to the two axes (activity and metalinguistic axes) allows an original communicative evaluation, outside any grammatical control. When the learner has difficulties to express himself, there are many incidental sequences (to the benefit of the learner). On the other hand, when the learner expresses himself more easily, the dialogue tends to follow the activity axis. If we control in real time the evolution of the linear regression, we can evaluate the tendency of the learner's communicative ability. Let φ be the slope of this line; if the first derivative $\partial\varphi/\partial t$ is positive, incidental diagrams are more frequent, which can indicate metalinguistic sub-dialogues. On the other hand, if $\partial\varphi/\partial t$ is negative, the structure of the dialogue tends to approach the

activity axis, which can indicate an improvement of the learner's communicative ability (fig. 7).

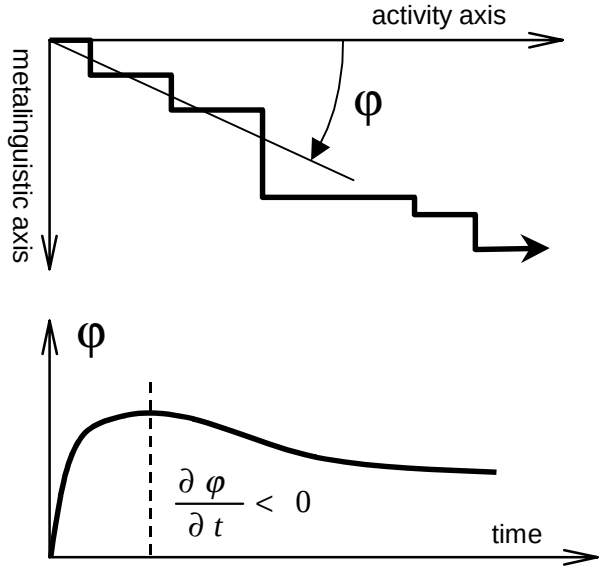

Figure 7: Evaluation of the learner's communicative ability

Model of the Activity

To model the activity, we use a Task-Method paradigm which comes from Problem-Solving in Artificial Intelligence [Trichet & Tchounikine 99]. This model makes it possible to break the activity down and to provide an applicative context to analyze the learner's utterances. Moreover, this breaking down ensures pedagogical strategies during the interactions. The formalism discerns the tasks and the methods. A task is a stage of the activity which can be explained, described or broken down. All the tasks structure the activity in the shape of a task-tree which can be explored at several levels of granularity. A method is a way to carry out a task. A task can be generally carried out by several methods. We can differentiate *decomposition methods* which break down a task into subtasks, and *operational methods* which constitute the leaves of the task-tree by determining the procedure to carried out.

From tasks to methods

The following examples (fig. 8) detail two tasks and two methods. The first task is an example of a high-level task which will be the root of the task-tree. Several methods (method A, method B, *etc.*) are possible to carry out this task. The formalism specifies the resources which are necessary and the new resources we have after the achievement of the task. "Method A" is a decomposition method to carry out this task. The second task is an example of a low-level task which will be used to take any object during the activity. The first operational method to take an object consists in clicking on it with the mouse. The second operational method consists in writing a sentence in natural language.

Example of a high-level task:

Task	**To make a chocolate cake**
Resources	Eggs (2) + flour (150g) + chocolate (1 tab) +
New resources	Chocolate cake
Methods	Method A: to make a chocolate cake; Method B: to …

Example of a decomposition method:

Method	**Method A: to make a chocolate cake**
Type	Decomposition
Tasks	1. To take three eggs, 2. To take a container, *etc.*

Example of a low-level task:

Task	**To take (x : object)**
New resources	x
Methods	Method A to take (x : object) ; Method B to take (x : object)

First operational method to take an object:

Method	**Method A: to take (x : object)**
Type	Operational
Procedure	To click on x with the mouse

Second operational method to take an object:

Method	**Method B: to take (x : object)**
Type	Operational
Procedure	To write a sentence which means "to take x"

Figure 8: Examples of tasks and methods

Links between dialogue and activity

Let us stress the fact that the activity is only a support to learn and practice a foreign language, not cooking! The role of the activity is to bring the learner to dialogue with the system. That's why it is essential to prompt the learner to use natural language as far as it's possible. One of the goals of the dialogue engine will be to exploit this knowledge (sometimes by using dialogue tricks) in order to force the learner to dialogue.

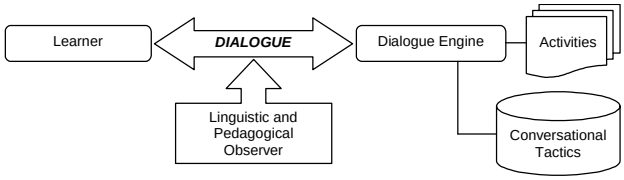

Figure 9: Place of the activity knowledge in our architecture

We have mentioned in the introduction two conversational modes: comprehension and expression modes. In each mode, the activity is divided into two:

Activity 1: Searching the ingredients. Before starting the recipe, the learner has to get all the ingredients needed. He searches in the kitchen, guided by the system. Consequently, he first gains knowledge of the lexical field of the

recipe, takes time to discover new ingredients and to visualize them.

Activity 2: Making the recipe. Now, the learner uses the ingredients and does actions (like mixing, measuring, *etc*.), in order to cook the recipe in a bowl. After each sub-action, the content of the bowl is modified, and the learner can see the recipe going on step by step.

In order to make these activities cause dialogue, the dialogue engine implements generic tactics based on the model described above. For example, the system will give very general orders using general tasks to bring the learner into asking how to carry out this task. The system can then give the first subtask after having decomposed the task by using one of the decomposition methods. Dialogue n°1 is based on such conversational tactics.

Model of the Language

We distinguish two kinds of linguistic knowledge: the knowledge to let the system dialogue in natural language with the learners (the linguistic performance) and the knowledge to evaluate the statements of the learners and assess their level (the linguistic competence). This distinction between performance and competence is essential in our approach. In figure 10, we place these two kinds of knowledge on our architecture: the knowledge for linguistic performance is associated with the dialogue engine and the knowledge for linguistic competence is associated with the linguistic observer.

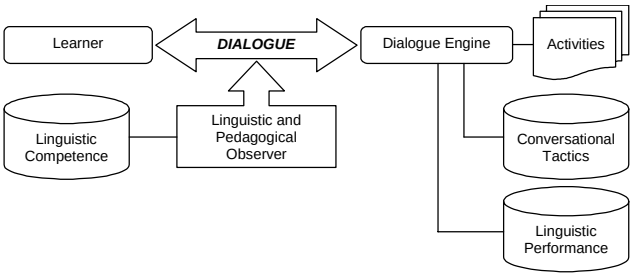

Figure 10: Two kinds of linguistic knowledge

To enable the system make a linguistic profile of the learner, we need to integrate linguistic tools, e.g. systems which, using a learner utterance, provide an analysis according to their specific competence (most of them are devoted to a specific aspect of the language: grammar, syntax, phonology, *etc*.). Consequently, each of these tools has a partial view of the learner's utterance, and cannot handle a global linguistic diagnosis by itself. We believe that a way to bypass this limitation is to integrate different points of view, different tools. After several experiences, we have noticed that a simple concatenation of several tools leads to shortcomings in the error diagnosis or to conflicts between diagnoses. In order to address these problems, we propose to use collaboration (to fill shortcomings) and negotiation (to bypass conflicts between tools) so as to get a global error diagnosis, a global point of view of the learner's utterance. In this paper, we don't develop these aspects any further.

The linguistic performance must take account of the specificity of the system (using a foreign language) and especially of the need of having a robust analysis of the statements. Indeed, the dialogue process should not be blocked because of a too lax use of grammar: such a system must be able to accept atypical or ungrammatical statements. That's why we do not base this knowledge on a normative grammar. In the same way, we do not base the analysis process on the construction of a syntactic tree but on the finding of morphosyntactic and semantic clues. Our lexicon[1] integrates concepts such as collocation or actant structures which take into account semantics as early as possible in the process of interpretation.

First, the lexical items are combined into *semantic classes* and structured as trees to define an ontology. For example, the butter, the flour, the sugar are ingredients; the bowl, the measuring jug are containers; the spoon, the whisk are kitchen utensils; the gram, the pinch, the packet are measures, *etc*. As regards the actions, the lexicon combines general actions like to take, to pour or to dissolve, and more specialized actions like to separate the whites from the yolks or to beat the egg whites. Secondly, semantic and syntactic combinatory properties are associated with each lexical item (syntactic patterns, actant structures, lexical functions). This lexicon is based on the *model of explanatory and combinatory lexicology* [Mel'cuk & al. 95], [Wanner 96].

Lexical entry	**"to take"**
Category / tag	Action verb
Valence	1 or 2
First actant	A1: Inanimate and light object (ingredients, container, *etc*.)
Second actant	A2: Place of the first actant (optional)
Syntactic patterns	To take A1 ; To take A1 off A2 ; *etc*.

Figure 11: Example of a lexical entry

Thirdly, we identify for all the lexical items of a same semantic class, the syntactic and lexical properties which are inherited. The polysemous items have the advantage of a multiple heritage. This lexical study makes it possible to build statements where the learner will be guided in a systematic training to acquire the semantic structures of a foreign language. The following section clarifies the links between the linguistic and the activity knowledge.

Of course, the system has to master several semantic fields such as cooking and task-resolution semantics to progress in the making of the recipe, kitchen and spatial semantics to use the Virtual Kitchen (fig. 14), and also meta-linguistic semantic to negotiate the linguistic level.

[1] The studies on the lexicon are carried out by Myriam Bouveret [Bouveret 98], [Bouveret & Lehuen 00].

Links between language and activity

The lexicon must have its own existence to be isolated and exploited as such. That's why it should not merge with the task and the method of the activity knowledge. The linguistic and the activity knowledge must maintain connections which will enable them to be used together in a suitable way. Thus, the tasks and the methods must be verbalized as instructions, explanations, questions, *etc*. In the same way, some parts of the utterances must enable the system to invoke the underlying concepts (process of denotation).

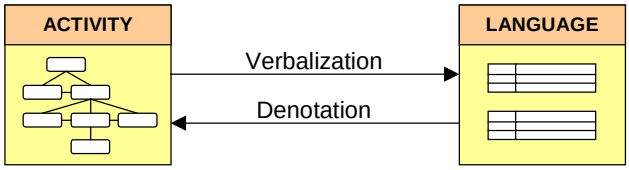

Figure 12: Links between language and activity

For example "to take the whisk" requires the T003 task where verbalization slot points to several lexical entries (fig. 13). Thus, the system reaches all the properties of the lexical entry "to take" and is able to answer any question from the learner. Conversely, the L231 lexical entry denotes the T003 task.

Task T003	**To take (x : object)**
- - -	- - -
Verbalization	L231, L232, *etc*.

Lexical entry L231	**"to take"**
- - -	- - -
Denotation	T003, *etc*.

Figure 13: Examples of verbalization and denotation links

Prototype and Experimentation

The Virtual Kitchen

Our goal is to build a conversational system which is effective for learning, and significant for the learner's model. We have developed a prototype of our system to validate the activity and to carry on an experimentation. The latter is made up of a "virtual kitchen" and of a dialogue box (fig. 14). Consequently, the learner can link two representations of a concept: a verbal representation, given by the system in the dialogue box, and a visual representation, simulated in the virtual space. Pilkington and Parker-Jones develop the idea that *through the direct manipulation of objects, visualization becomes easier and, through visualization, abstract reasoning in the domain becomes possible* [Pilkington & Parker-Jones 96]. We think that simulation is the best way for a learner to internalize the language, by using it [Boylan & Micarelli 98].

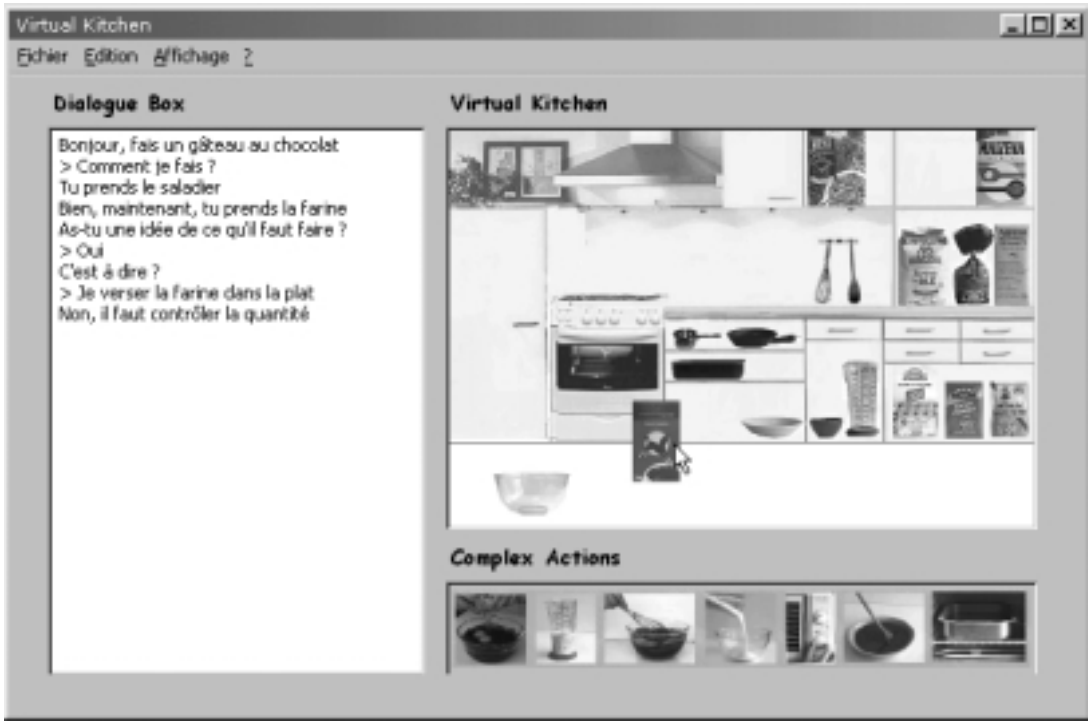

Figure 14: Prototype of the Virtual Kitchen

The first experimentation

For the first experimentation, we carried out a "Wizard of Oz" study: a French teacher played the role of the system in the dialogue box. The utterances and the actions on the virtual kitchen were coded and written on files. Five foreign students learning French have participated. They had an intermediate level in French (mostly an oral ability), knew French culture as they had lived in France for at least six months. They were between 22 and 28; three women and two men, of five nationalities: Lithuanian, Mexican, Equatorian, Nepalese and Russian. Only one student did not master computer. The others were familiarized with computer, and went regularly to the multimedia language resources center. They all had a positive opinion on the use of new technologies for learning.

The experimentation has lasted one hour per learner. They had to make a (virtual!) chocolate cake, following the system's (e.g. the French teacher's) recommendations. We did three evaluations. We started with a personal evaluation of the language ability, by discussing ten minutes with the learner. Then, we observed his/her reactions during the simulation. Afterwards, we asked the learner for his/her feelings about the system, the advantages and the problems he/she had encountered.

Our first goal, the validation of the activity, has been reached: we have observed learners achieving the activity and the linking between the two spaces of the screen (dialogue and graphic). The learners were also satisfied, they found it motivating and felt they had been learning about French culture. The second point, the acceptance of mistakes, has also been very well perceived. They all started being very afraid of making mistakes, and step by step, felt more confident, and were concentrated on the task, not on the grammar.

Conclusion

To complete our architecture, we have to include the learner's model and the pedagogical and didactic knowledge which is essential for such a system (fig. 15). In this paper, we have focused on the dialogue subsystem and we haven't developed any aspects of the pedagogical subsystem. Let us mention that the "Linguistic and Pedagogical Observer" module has to update the learner's model and can take control of the dialogue engine to engage a metalinguistic sub-dialogue. It needs some knowledge to decide at any moment whether the dialogue engine must break off and negotiate the learner's mistakes or not. *A negotiative ITS must therefore know on what aspects it is willing to negotiate and on what aspects it is not, for a given learner* [Baker 94].

Let us now position our approach with regard to the plan-based approach [Schank & Abelson 77], [Allen & Perrault 80], [Wilensky 83], [Litman & Allen 87], *etc*. In the plan-based approach, the authors develop systems that could infer discourse plans as well as traditional domain plans. We don't reject this plan-based approach but, in this work, our main goal is neither to carry out a task efficiently, nor to improve the system's understanding, but to bring the learner to dialogue with the system. In this perspective, the use of a plan recognition process is not essential. Nevertheless, the planning aspects are present at the activity level through the Task-Method paradigm. At this stage, we don't want to use the same paradigm for the discourse and for the domain. When we work on the pedagogical subsystem, we will probably introduce several aspects of the plan-based approach to carry out negotiation and collaborative subdialogues [Carberry & Chu-Carroll 98], [Carberry & Lambert 99].

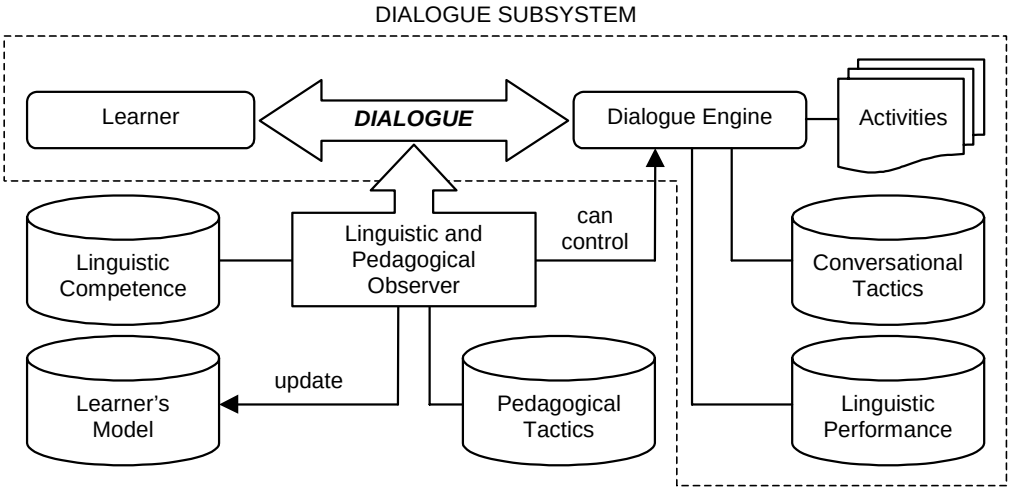

Figure 15: A dialogue-based architecture for Computer Aided Language Learning

At the moment, the first "Wizard of Oz" experimentation allows us to validate the approach and the activity. Apart from this, our dialogue engine has been implemented in several systems and has been validated too. We are now developing the interpretation process to allow robust understanding. After, we will work on the link between the virtual kitchen and the dialogue engine by implementing activity rules and conversational tactics. This will lead us to a second experimentation. Afterwards, we will integrate existing linguistic tools to control the lexical, the morphological and the syntactical aspects of the learners' utterances. Then, we will be able to work on the learner's model and on the pedagogical tactics.

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