Proposal for a Vygotsky's theory based approach for learning in MAS

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Abstract

According to Lev Vygotsky, learning is influenced by social interactions and this confrontation of points of view enables an individual to evolve during the time. The Vygotsky's theory gives a quite important place not only to social tools as language, but also to interactions and relationships between individuals. Therefore, we try to see how, in a multi agents system, an "intelligent agent" can learn and more easily integrate a new environment and a new agent's community. This paper proposes our ideas on that topic and tries to give a modeling of the adaptive agent's behavior in the framework of multi agents systems (it should be noted that it is a work in progress).

1. Introduction

Social behaviors, in particular social learning, are key mechanisms to the evolution of human societies. We can find many examples of this basic way of learning: a teacher trains children read and write, parents teach their children playing and sharing some activities with other, children work together at school to find a solution to a problem… Cooperative learning is not new and has been studied since at least the 1920s. Until the Eighties, benefits of group learning were hardly questioned and research into this way began to lead to some fundamental doubts about its effectiveness. It was proved that although children might be seated in groups, they still worked predominantly as individuals. Analysis of dialogues between pupils in working groups demonstrated very little of the discussion really supported the task performance. But group learning is an area in which active research is needed. Currently, with the growing interest in Vygotsky's theory, analysis of the role of social interactions in Piaget's work (Beilin 1992, De Vries 1997), Bandura's reformulation of the individual in reciprocal relations with the social environment (Bandura 1980, Bandura 1989), social and cultural contexts and interactions were considered in the study of individuals' learning.

Therefore, in multi agents system, social competences are considered important for artificial agents who want to interact with other agents in order to learn. As a matter of fact, learning in multi agents systems appears like an efficient solution to maximize the performances of all actors in the system. Thus, any agent can learn the strategic behaviors of its partners and react more easily to each situation. Learning in multi agents system can't only be used at the agent's level but also at the level of the system itself (we speak of "collective" learning by sharing information and beliefs) (Weiss 1993). Several questions are going to emerge in learning process:

- Why and what to learn?
- How to learn?
- With who to learn?
- If agents are different and use words that haven't the same meaning, can they learn also from the other? How do they learn new meanings if it is possible?
- Can we consider communication as an original solution of learning in multi agent system? If we can, how take it in account?

From these two observations in psychology and distributed artificial intelligence, we wondered how an adaptive "intelligent" agent could learn by mean of its interactions with other agents and thus more easily integrate an unknown environment[1].

This article is subdivided as follows: Section 2 presents briefly the foundations of Vygotsky's theory, basis of our analysis. Section 3 describes the different steps of a new agent's integration and Section 4 concludes on this work.

2. Vygotsky and the social development theory

"The main activity of all human beings consists in giving meanings to its meetings with the world" (Bruner 1960). This sentence of Jerôme Bruner summarizes the project of Lev Vygotsky: to put more emphasis on the importance of cultural and social interaction in the evolutionary process. Vygotsky considered cognitive developments as a result of a dialectical process, where the child (Vygotsky 1962) learns through shared problem solving experiences with

[1] Like James Odell (Odell et al. 2002), we consider that an agent's environment consists not only of an agent itself, but also those principles and processes under which the agents exist and communicate.

someone else, such as parents, teacher, siblings... At the beginning, the person who interacts with the child undertakes most of the responsibility for guiding the problem solving, but gradually this responsibility is assumed by the child. Although these interactions can take many forms, Vygotsky focuses on language dialogues. It is primarily through their speech that adults are assumed to transmit to children the core of knowledge existing in their culture. In his learning process, the child develops his own way of communication as a primary tool for his intellectual development. So, children have a mean to control their own behavior in such a way their parents did it. This transition reflects the Vygotsky´s idea on the development as an internalization process. Knowledge and way of thinking are exogenous concepts related to children and endogenous concepts related to the cultural environment. Development consists of gradual internalization, primarily through language, to form cultural adaptation. To illustrate his ideas, Vygotsky gives the example of children's learning: "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This involves, in a same proportion, voluntary attention, to logical memory, and to emergence of concepts. All the higher functions originate actual relationships between individuals" (Vygotsky 1978).

Vygotsky also believes that language plays an important role in development (Vygotsky 1962). It develops indeed not only the intelligence of the individual but also all the whole learning process as the result of his communication and his collaboration with the others. The work undertaken by Vygotsky provides a powerful foundation for social learning in any phases, especially with his concept of "the zone of proximal development" (Doolittle 1997).

2.1 Zone of Proximal Development (ZPD) and scaffolding

Vygotsky describes this zone as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky 1978). In other words, a student can perform a task under adult guidance or with peer collaboration that could not be achieved alone. The Zone of Proximal Development bridges that gap between what is known and what can be known. Vygotsky claimed that learning occurred in this zone. To facilitate learning in the ZPD, Wood (Wood 1976) introduces the concept of scaffolding. It was one of the ideas to give a support to learning with children. In this method, children learn best through assisted discovery. The teacher changes quality or quantity of support given to the student during the teaching session. This action completed by the teacher is known as scaffolding. Vygotsky suggested that the zone of proximal development, or what can be completed with help, falls between what cannot be completed alone and what can be solved independently. As learners become more competent, the teacher gradually withdraws the scaffolding so learners can perform tasks independently. The key is to ensure that the scaffolding keeps learners in the ZPD, which is altered as they develop capabilities.

This way to conceive learning supposes that it is preferable to work in a cooperative way and to encourage interactions with others for the construction of knowledge by means of a socialization tool: the language.

2.2 Role of language in social development

Vygotsky "viewed intelligence as the capacity to take benefit from instruction, with language having a powerful developmental role" (Spencer 1988). In this meaning, language is a tool for learning and an aid for understanding. As Vygotsky noted (Vygotsky 1978): "human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them". Therefore, language acts as a vehicle for educational development and is important for knowledge understanding and knowledge acquiring. The main purpose of the language is social. With language, peer collaboration can be involved. When peer work together in cooperative tasks, the shared social interactions can be used in instructional mode. Research shows the following facts:

- if any trainee has a precise responsibility
- if any trainee is able to reach a given level of competence

before the whole group can progress,
then cooperative learning in groups is more effective for the trainees than individual learning.
This peer collaboration attests the well-known impact of the social environment during learning.

As we see with Vygotsky, the learning process can be divided in two steps: first, the individual can learn alone and secondly, the individual can learn by mean of his interactions with the others. On the basis of this assumption, we tried to apply this theory to a multi agent system. We show how an "intelligent agent" (Ferber 1995; Wooldridge and Jennings 1995) could learn by mean of its interactions with accointances and to more easily integrate a new environment. In section 3, we will describe different steps of the integration.

3. An agent in a new environment: steps of its integration

We assume an environment in which different agents move and communicate by sending and receiving messages (standard format messages used in MAS: FIPA-ACL (FIPA 2003)). We also suppose a new adaptive agent appears which wants enter this new environment. This agent has capabilities to learn, to communicate and initially has a basis of words and a set of words which characterizes its ontology. In our approach, we postulate any new agent has an "a priori" ontology from which it is able to define a given word inside a context. We consider that it doesn't know any word of the environment in which it wants to integrate. So, its "a priori" ontology can be inadequate and the agent can hear some words it is unable to understand related to this ontology. Therefore, it has to perform an integration process in view to modify its ontology. This can be made by creating and dynamically maintaining a basis of words.

We assume that integration process of the agent is performed in three steps: a first step of listening and monitoring, a second step of questioning and assimilating new words, then, during the last step the agent could find its place and the role to play in the new environment. We are going now to describe each of these steps and to progressively develop a small example for a better understanding of our reasoning.

3.1 Step 1: listening all conversations

In order to have a basic knowledge on the other agents and their roles in this environment, the new agent is going to operate, in a first time, a "passive listening" of all exchanged messages. During this process, the agent is going to analyze every message, to extract different words and try to associate each word to a concept, and then, according to their degree of importance, to store all words a basis of words.

Let's give an example: during communications, the new agent (agent N) intercepts all messages and notices that the word "operator" is often used and employed in conversations. So, it extracts this word, looks if this word is used in agreement with its ontology, and then, put it in a basis. If this word is used in agreement with its ontology, it will have to ask for a confirmation on its significant during the second step.

When agent N intercepts a message of another agent, in a first time, it must decompose the message in order to extract its content and to take apart the useless words which describe the message structure (as the type of the communicative act, the participants to the act, the delay of answer...). The following example illustrates a communicative act, according the FIPA standards.

```
(inform
      :sender A
      :receiver B
      :reply-with laptop
      :language KIF
      :ontology ordinateurs
      :content (=(prix HP-Jet) (scalar 1500 USD))
      :reply-by 10
      :conversation-id conv01
      )
```

So, in this step, information contained in the different messages exchanged by agents must be extracted. The extraction of information, which consists to automatically creating a bank of data from written texts (Poibeau 2003), is particularly well adapted to our situation. Indeed, our objective is very simple: agent N must search new words containing in different exchanged messages and classify them in a basis according to their degree of importance. Therefore, an advanced extensive and semantic analysis of the messages would be too long and inappropriate in our case. A local and precise analysis through textual indications (points, spaces, personal pronouns…) is more adapted. Moreover, researches in the domain of automatic understanding of texts knew an important renewal with researches in information extraction. Indeed, it was a very active domain in the United States since the end of the 80's with MUC (Message Understanding Conferences) organized from 1987 to 1998. One of the examples given in these conferences (MUC-4 1992) is to try to extract some information concerning terrorist scripts from the narrations of attempts in Latin America. Thanks to a linguistic analyser, participants must extract some information on this attempt, the authors… Besides the funny character of this simulation, it permits to show the importance of the linguistic analysis in this domain. From this, adaptation of this technique for information extraction to our example is very interesting in multi agents' domain.

So, for our new agent, this analysis process is essentially decomposed in two steps:

- **A linguistic analysis** founded on the recognition of the words having for goal extraction of new words. An analyser, which is composed of a given number of filters that is executed one after the other, is used. These filters permit to make different operations on the messages: decomposing the message in words while localizing the signs of punctuation, suppressing frequent functional words which have not a sufficient discriminative value to be interesting in our research (determinants, personal pronouns…) and keeping the key words that will be indexed in the basis finally. This type of analyser is used as well in the domain of the treatment of written texts (Joly 1991) than in the treatment of the speech (Goulian 2000).

- **A statistical analysis** (Lebart and al. 1988) founded on the relative frequency of apparition of a word at the time of

the messages exchanges. It permits to quantitatively determine the importance of this word for agent N (we think that the most a word is used during a conversation, the most it will be useful to ask thereafter for the precisions).
These two steps can be represented by a small multi agent system in which some agents are responsible of linguistic analysis and others are responsible of statistical analysis. By adopting this technique, the first step of extraction will be treated more quickly and optimized.

The last point to enlighten is to know how long our agent N must stay in "passive listening" so that its basis of words doesn't become too important and redundant leading to management difficulties. For that, we impose an arbitrary time constraint provided that subjects contained in every message become repetitive and don't improve its understanding (remind messages are related to a precise working context). Event though this constraint can appear strong enough, we don't exclude that the new agent learn new words once its integration is made.

As soon as this phase of listening ends, our agent N is going to learn all new words in order to more easily communicates and interact with the other agents: this is the second step of integration, the step of questioning and assimilating new words.

3.2 Step 2: questioning and assimilating new words

For every unknown word in the basis, the agent is going to try to learn it while questioning the other agents on its semantic and its use (in a first time, it will summarize to define a concept to a word).
Two cases can occur:

- **Two definitions at least are in concordance**. The word is automatically assimilated by the agent N. The ontology (as ontology, we consider the definition of Jean Charlet (Charlet et al. 2004: "an ontology is defined as the conceptualization of the objects recognized like existing in a domain, their properties and relationships joining them") is updated to take in account the new meaning of the word in context. For example, all agents agree to say that the word "operator" is a switchboard operator. So, agent N can relate this word in its ontology to the concept "Telecommunications".

- **Several definitions appear**. Agent N must choose what definition it wants to learn. For example, some agents say that an operator is a switchboard operator and others consider that an operator is a sign in an operation. So, agent N can relate this word in its ontology to the concepts "Telecommunications" or "Mathematics". The question is to know how agent N can make such a choice.

To solve this problem, we make the hypothesis that agent N can give more or less credibility to the answer given according to the confidence level towards the interlocutor. This confidence level may be defined during the first step of integration (the "passive listening"), considering the information exchanged by every agent (i.e.: to assign a bigger confidence to an agent that regularly acts, to try to distinguish if an agent has a greater knowledge compared with the other…). For example, let's suppose we have three agents in a cooperative environment: any agent must give an answer to any other agent. Agent N enters the system and observes that agent 1 gives a more technical answer than agent 2 and agent 3 gives few answers. So, agent N will have more confidence in agent 1 and agent 2 than agent 3 and have also more confidence in agent 1 than in agent 2.

In order to confirm or not his hypotheses, the new agent can also question every agent on another agent (i.e: is an agent always considered by the other as an expert in this domain…). In our example, agent N can ask agent 3 if he considers agent 1 is more qualified for some questions than agent 2.

During this step of questioning, if in the case of a competitive environment, agent N must also discern if the answer given by the others are coherent or not and try to know if an agent lies or not (Has this agent some divergences in the answers that it gives? Does it have a given interest to give some bad information?...). If the new agent succeeds in detecting a lie, it will assign a very little value to the confidence level of this agent and exclude it of people to question.

At the end of this step, our new agent acquired some "expertise" in this new environment and some point of view on the other agents. So, it can integrate the new environment.

3.3 Step 3: successful integration of agent N

Our new agent having learned all useful notions for its integration in a new environment, it also can exchange messages with the other agents, find a place in this environment, and confirm or not the point of view that it has on the other agents. In our example, when agent N uses the word "operator", all the other agents understand it. Also, we can imagine that our agent N has already used this word in another environment with a different meaning. So, the word "operator" will be related to two different concepts in its ontology.

In this last step, we don't exclude the fact that the agent can again acquire new words that didn't appear at the time of its arrival but that occur during the time. In this case, it should question some agents that it will consider the most capable to provide it some right information.

4. Conclusion

In this article we developed our propositions on the way to consider the arrival of a "naïve agent" in a new environment and its interactions with others. We also see that the learning process requiring interventions of other agents and passed through some socialization artifact: the language, which is the bridge for connecting teaching and learning. So, we consider that communication plays a crucial role for individual cooperating or competing to achieve mutual goal. It is the basic mechanism for coordination in organizations. Generally speaking, the function of communication is to ensure that every member of a group knows and understands what is expected. Good communication ensures individuals know what is expected of them, that the appropriate person receives the correct information and that there is coordination in the group. It is the same thing in multi agent system: if communication between agents is poor, not clear and not concise, coordination between agents will be ineffective and disorganized.

We also consider in this article the notion of learning and especially social learning. We take opportunity to remind that some a distinction exists between a learning process and an adaptive process. Indeed, we consider, as Tom Mitchell (Mitchell 1997), that there is learning process when a system acquires new knowledge and becomes more effective whereas there is adaptive process when a system faces new conditions without becoming more efficient or to learn new things. In our case, we consider that we are in learning's process because our agent acquires a lot of new concepts to be able to improve its benefit within the group. We also think that it is a quite important problem because new agent doesn't know "a priori" the exact structure of the environment and it must learn it from its interactions with other in an uncertain and complex domain. However, individual learning isn't sufficient for complex missions of autonomous agents. Cooperation among agents during learning is also essential like working on similar task and coordinating the actions in a group.

Although we don't have any practical results again, we consider that our approach is quite original by the fact an individual agent uses interactions and communication in a group to learn. We consider communication between agents as a key concept for the learning process. Indeed, we really agree with this Vygotsky's sentence: "the contribution of learning is due to the fact that it provides to the individuals a powerful artifact: the language".

We also have many suggestions to improve our model such as trying to evaluate the performance of the learning process of our agent.

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