A new interaction model for agent based simulation

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ABSTRACT

In this paper, we propose an interaction model which allows more realistic interactions for simulations of human societies and limits the communication cost. Interaction is a central concept when designing a multi-agent system. Classically, interaction between two agents contains two elements: communication and the action which is the result of this information exchange. This view of interaction has underpinned most research in the multi-agent domain. However, if we draw an analogy with human behavior, the notion of interaction is more complex and we show that the classical ways of interaction managing are not adapted. To reach this objective, the environment could be used to mediate interaction between agents. A toy problem shows that our proposition helps the agents to adapt their perception of communications in the light of their interest and limits the communication cost in case of complex interactions between agents. A real application stemming from the transportation domain illustrates the use of our proposition to help agents to adapt their behavior to the context.

INTRODUCTION

Interaction is one of the central concepts for the design of a multi-agent system (MAS). In the methodology called Vowel (Demazeau 1995) interaction is placed at the same level as agents, the environment and organization. That is why a multi agent based simulation has to make a choice about this component. As it is recalled in (Weiss 1999) for the multi-agent paradigm, interaction between agents contains two elements: communication and action which is the result of the information exchange. This dichotomy has underpinned most research. In the reactive agents community, communication is limited to the exchange of signals and the action result to the activation of the associated reflex. In the cognitive agents community, the communications are organized by protocols which determine the order in which the messages are exchanged. The action element is based on the analysis of high–level languages and on the analysis of the content representation language. However, this classical view has limits. Whereas the action of a communication on the receiver is taken into account, there does not seem to be any work concerning the action of a communication on the other agents of the multi-agent system. If we define the agent context (in the broad sense) as the set of information and events of which it has knowledge, the interaction context of an agent can be defined as the constituent of its context relative to interactions. Since the impact of an interaction is limited to the protagonists and has no impact on the activity of the MAS, the classical view of interaction is a powerful limit to the interaction context of an agent. In the same way that has been identified a problem of scale when using the classical concepts of interaction in MAS for the modeling of modern human societies (Malsch and Schaeffer 1997), this paper shows that the classical view of interaction is insufficient for the modeling of highly interactional systems such as control centers (Salembier 1994). Interaction is based not only on pre-established protocols but also on the attention of the interactional activity of the participants. In multi agent based simulation and particularly in the domain of simulation of social theory (Castelfranchi et al 1992) or simulation of real human activity (Balbo 2002) (Dugdale et al. 2000), there is a need for complex interaction. The question is: what happens when agents located in the same place communicate? Indeed if the modeling of human operator is a difficult problem (Norling et al. 2000), enable them to interoperate in a realistic way is another difficulty. This paper shows that the use of classical means to organize interaction increases the communication cost. In multi-agent simulation area we propose the use of a medium (the environment) to enable the agents to participate in common conversations according to the context. For the receiving agent, the matching of the reception conditions of a message with the content improves the understanding of the interaction context.

The second section presents the issues addressed; the third section explains the modeling of Environment as Active Support of Interaction (EASI). The fourth section shows the evaluation of our proposition for a toy problem and its use for the treatment of a real problem. The last part is our conclusion and suggests future lines of research.

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TOWARDS A CONTEXTUAL INTERACTION

Interactional gaps

Traditionally, the communication mode of reactive agents (non-addressed communication) is contrasted to that of cognitive agents (addressed communication). In the case of a non-addressed communication, the environment enables the agents to interact by the perception of stimuli or modifications to the environment. In this framework, the sender of the stimulus does not know the receivers of its information and it is the environment which, with physical rules such as proximity, determines the protagonists of the interaction. Each agent is potentially a participant in every interaction and its characteristics and those of its sensors determine whether or not the interaction will happen. The reception context of a stimulus is thus dependent on the application of physical rules which are beyond the control of the protagonists. Reactive agents do not exchange structured messages in compliance with protocols and have therefore mainly been used for simulations of insects on which such work was based.

Interaction by means of addressed messages allows the creation of complex protocols. For an agent, the context of an interaction is thus often dependent on the current protocol. To facilitate the matching of the sender's needs (requests) with available competences within the MAS, much research suggests specializing agents in the processing of interactions (Decker et al. 1997). But, whereas human beings working in the same environment have other sources of information (their senses) to perceive the activity of their partners, agents are unable to perceive the interactional activity of the other members of the MAS. However, it has been agreed in the definition of the agent paradigm that an agent has to perceive the world in which it evolves. If the simulation environment of an agent contains a communication part then the simulation needs a specific interaction protocol to avoid the agent isolation. The problem is that if the knowledge necessary for interactions is delocalized within specialized agents, it is not able to perceive the interactional context.
Nevertheless, an interactional act between two agents is itself a piece of information. For example, in a control center the attention of the operators is not limited to their own interactions but also to those of the others. The concepts of floating perception (Salembier and Zouinar 1998) or mutual awareness (Dugdale et al. 2000) illustrate this need and are used to express the operator's way of managing their attention to events. These events can take various forms: a message which is easily usable in MAS, an agent signaling interest for another agent. In this case, information does not concern the message itself but the perception of the exchange of messages between two agents at a particular moment. Consequently, the interest of the agents is guided by the interactional context in which they function.

Using the environment as medium

It is clear that the use of the environment by the reactive agents in order to interact does not allow an exchange of complex messages. Similarly, the use of addressed messages often supposes a more or less distributed management of the knowledge necessary for the interaction. These two interaction modes have gaps but their combined use opens a third way. This third way has to enable cognitive agents to design their interactional context. In other words, the aim is to allow an agent to specify the conditions in which it wishes to perceive interactional events. To reach this objective, cognitive agents should use the environment as a support for their communications.
The principle of an environment common to the agents is central in the reactive agents community. In this paradigm, the agents have sensors so as to perceive the environment, and effectors so as to act on it. If extended to cognitive agents, the common environment would be an interaction medium that each agent could modify by its own interventions (i.e. sending of messages) and perceive by means of sensors. An MAS is no longer designed as a sum of communications which are organized with protocols, but as an interaction medium where each message can be perceived independently of the initial needs of its sender, its receiver and their current protocol.
It must be possible to exchange complex messages (cognitive agents) and the agents must be able to perceive in the environment the messages they should receive (reactive agents). The exchanged messages can be addressed or not. The exchange of addressed messages supposes the use of pre-defined protocols. The use of the environment conditions the reception of a message to the perception capacities of the agents. In this way, each agent defines its own interactional context.

The aim of the present research is to propose a model extending the use of interactions between agents. The problem is to bind an interactional need of an agent not only to its own state but also to the state of the world. The introduction of the notion of context in the interaction protocols allows the agents to specify the conditions in which they wish to be concerned by an interaction and by extension to reconstitute more easily the context in which they are receivers of a message.

ENVIRONMENT AS ACTIVE SUPPORT OF INTERACTION: EASI

The reactive agents community has produced a modeling of the agents from their perception of the environment to their reaction. This could be extended by modeling the perception filters of the environment used by cognitive agents.
The example below illustrates the various components of the proposal. It is followed by a presentation of the

EASI model, which is a generalization of our initial work (Balbo 2002). A use of our model is presented in the last section.

Example

To illustrate our model, let us take the following toy example: simulation of interactions within a classroom. The teacher and the individual students are each represented by a different agent. The classroom constitutes the common environment where interactions (exchanges of messages) between cognitive agents are perceptible to all. The figure below contains possible interactions.

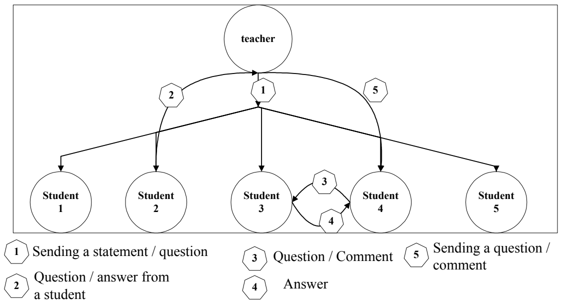

Figure 1. Representation of interactions in a classroom

The teacher gives information to the students who can ask questions (questions which the teacher answers). The students can also communicate between themselves to ask questions or to make comments. In the interactional context-building scenario, an agent chooses to perceive certain events according to its expectations. For example, a student wishing to go out of the room waits for another student to ask the teacher a question before carrying out its action. This agent is therefore interested in the interactional context of the MAS and not in the content of the exchanged message.

EASI model

In the following section, we give the minimal definitions which are necessaries to the understanding of our proposition.

For the reactive agents community, a tropic agent (Ferber 1995) is defined as a tuple:

$$a = < P_a, Percept_a, Reflex_a>$$

Where:

- P_a: set of percepts associated to an agent
- $Percept_a$: perception function which associates a percept to every state of the world
- $Reflex_a$: function which associates an action to a percept.

By extension, a cognitive agent perceiving communications in the environment is defined as:

– P_a: messages deposited in the environment and accessible to agent *a*. In theory every message in the environment is accessible to the agents present.

– $Percept_a$: set of perception filters enabling agent a to receive messages. It is the filters allowing the perception of communications which define the subset of messages perceptible to an agent.

– $Reflex_a$: activation of the reasoning process according to the message received (content and filter). How the agents consider the message will depend on its content and also on the filter that enabled its reception.

The environment is modeled using filters enabling agents to receive messages. The elements present in the environment will be noted:

$$\Omega = <\Omega_A, \Omega_M>$$

Where:

- Ω_A: the agents of the MAS
- Ω_M: the messages of the MAS

Each element in the environment is recognizable by a set of properties which are accessible by the environment.

Definition 1*: an entity*

An entity is any element of the environment that is made up of properties:

$$\omega \in \Omega, \omega = \{p(\omega) \neq null \mid p \in P(\Omega, D_\Omega)\}$$

Where

$P(\Omega, D_\Omega)$: set of the properties of the MAS

$D_\Omega = \bigcup_p D_p$: union of the definition sets

Definition 2: *an agent*

Let A be an agent category and *a* an agent of A, then

$$\forall a \in A, a = \{ p(a) \mid p \in P(A, D_\Omega)\}$$

An agent category is a set of common properties. An agent is defined as a member of a category and differs by the values of its properties. An agent has other components (knowledge or skill), but they are not useful for our interaction model.

Example: There is an unique agent category, that we called *person*. For each *person* we have three properties, the position in the classroom (*Position*), a unique identifier (*Identifier*) and the agent's role in the simulation (*Role*). The teacher agent (noted *T*) is defined with the tuple:

T: {0, 1, teacher}

Where:

Position (T) = 0
Identifier (T) = 1
Role (T) = teacher

A student, for example student 3 (noted *S3*), is identified with the tuple:

Student3: {3, 3, student}

With:

Position (S3) = 3
Identifier (S3) = 3
Role (S3) = student

Definition 3: *a message*

$$\forall m_o \in \Omega_M,$$

$$m_o = \langle \text{Sender, Receiver, Subject}, \bigcap_{l=1}^{n} C_{ijk}^{l} \rangle$$

Where:

- Sender: identifier of the sender.
- Receiver: identifier of the receiver.
- Subject: subject of the message
- $C_{ijk} = \langle p_i, f_j, v_k \rangle$
- $p_i \in P(\Omega_A, D_\Omega)$
- $f_j: D_{pi} \times D_{pi} \rightarrow D_{Bool}$
- $v_k \in D_{pi}$
- D_{pi} : domain of definition of property p_i.
- $P(\Omega_A, D_\Omega)$: set of properties of MAS.
- $\bigcap_{l=1}^{n} C_{ijk}^{l}$, The conditions under which the receiving agent has to meet to receive the message

A condition $C_{ijk}(\omega)$ is true if :

$$\omega \in \Omega \wedge f_j(p_i(\omega), v_k)$$

The definition of a message corresponds to the definition of the properties and gives us the semantics of the messages. This semantics is common to all the agents. By construction, the description of a condition becomes a property of a message.
Remark: the content of the message is not a parameter of our semantics.

Example: let M_1 be the message:
M_1 = <1, *unknown*, "question", <role, =, student> >
M_1 is a message sent by the teacher agent (identifier = 1) to an *unknown* receiver (the sender does not know its identifier) but with a property *role* value which is equal to student. That corresponds to the broadcast of a question (subject value) from the teacher agent to the student agents.

Definition 4: *a filter*
Let F_n be the nth filter of the environment.
$m \in \Omega_M$, $a \in \Omega_A$,

$$F_n(m, a) = (\bigcap_{l=1}^{l_a} C_{ijk}^{l}(a)) \cap (\bigcap_{l=1}^{l_m} C_{ijk}^{l}(m)) \cap (\bigcap_{l=1}^{l_e} C_{ijk}^{l})$$

Where:

- $(\bigcap_{l=1}^{l_a} C_{ijk}^{l}(a)$: Conditions concerning the receiving agent of the message.
- $(\bigcap_{l=1}^{l_m} C_{ijk}^{l}(m)$: Conditions concerning the message processed.
- $(\bigcap_{l=1}^{l_e} C_{ijk}^{l}(e_l)$: Conditions concerning the other entities identifying the interaction.

l_a, l_m, l_e: number of conditions for each entity category.

A filter links a message *m* to an agent *a*. An agent designs a filter with conditions relative to other agents and to messages e_l, thus allowing many possibilities in the management of its interactions. For example, an agent A can design a filter allowing it to receive the messages of agent B and conditioning its reception to the following interactional event: agent C sent a message to agent D. Consequently, it is not possible to represent the parameters of a filter without using sets of conditions.

Each filter enables an agent to receive messages according to conditions concerning some of the entities present in the environment. This set of conditions constitutes the interactional context in which the agent wishes to be contacted.

Example: F_1 is the filter allowing agent S3 to receive question sent by a student (identified by the variable a_l) to the teacher. The receiver will use the message for its content or as the event identifying an interactional context.

F_1 (m, a): <<sender(m), =, *b*>,
<subject(m), =, "question" >,
<receiver(m), =, 1>,
<Identifier (a), =, 3>,
<Identifier *(b)*, =, i_b>,
<role *(b)*, =, student>>

Having studied the first definitions necessary for the establishment of our model, let us now examine our example.

INTERACTION PROTOCOL COMPARAISON

Each student has a parameter called *attention.* This parameter determines the basis of the student behavior. It could take three values:

- **#0**: the student is inattentive; nothing that happens in the classroom has interest for him. Each received messages will not be treated except the teacher remarks.
- **#1**: the student listen but does not participate. The received messages are taken into account but he does not answer questions.
- **#2**: the student participates. He answers each question.

This basis attitude of a student evolves during the simulation. Each agent follows this rule: the higher is attitude, the less stable its behavior. This parameter is used to modify the interactivity level of our simulation.

In order to evaluate our proposition, we have compared it with standards of the multi-agent paradigm:
a) **Broadcast**: when the receiver of information is unknown, the receiver broadcasts the message to all agents.
b) **A middle-agent**: a specialized agent is the compulsory intermediary between agents. It receives and forwards each message only to agent having their

attention parameter value superior to #0. Because this parameter evolves during simulation, the agents must inform the middle-agent in case of modification of their state.

c) **Mixed**: the use of a specialized agent is required only when the number of messages may be decreased.

d) **EASI**: The value of the *attention* parameter is accessible by environment. Each agent has its own communication filter.

Scenario

In this scenario, the teacher sends questions to students and remarks to inattentive student. A student (S3 in the scenario) wants to use this event to become inattentive if its neighbor is itself attentive. This scenario supposes that S3 adapts its behavior according to two different information sources. Moreover, the aim of S3 must remain secret and that suppose that there is no particular protocol to optimize the communication cost.

To remain this intention private, each agent has to know the value of the parameter *attention* of the other. This hypothesis is necessary to simulate a student who observes the behavior of the other in the classroom. That is why the interaction protocol has to deal with the value updating of the *attention* parameter (Figure 2).

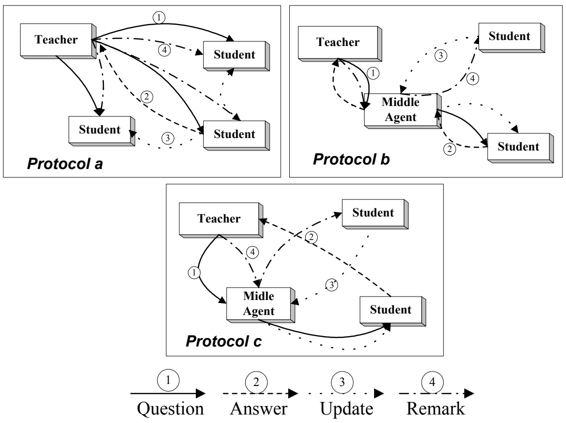

Figure 2: Interaction Protocol.

Since the two information sources are independent, only agent is able to evaluate them according to its interest. The consequence is that during the simulation each information has to be sent to each agent. That is why a mechanical increase of the simulation time (figure 3) and of useless messages (figure 4) is observed.

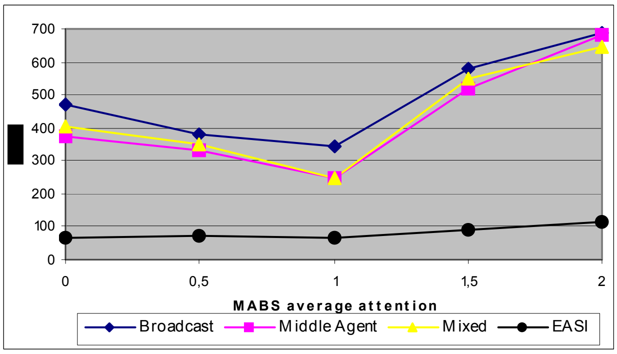

Figure 3: time evaluation

At each message a process time is associated. Because of the behavior rule and the design of the simulation, the value of the average attention determines the number of exchanged messages (update and answer message).

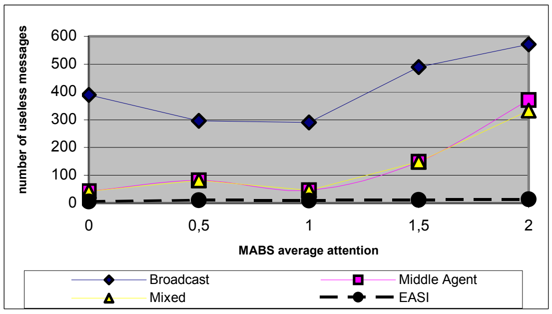

Figure 4: useless messages

For a student, a message is useless if its attention is null. For MAS, a message is useless if it is due to the protocol and not to its activity. The update messages are useless because they are the consequence of a protocol (the interaction knowledge is delocalized).

APPLICATION

The first domain in which, the proposal was applied is that of transport. Our application, called SATIR (Balbo 2002), illustrates in a very dynamic situation (regulation of an urban transport system) how an event-based interest in interactions was used to manage the inconsistency in the location of vehicles and how the reception context of a message enabled the agents to adapt the way they manages the inconsistencies.

Urban public transportation systems are naturally open systems (vehicles appear in or disappear from the network according to their activity) and distributed systems (vehicles move on a network).The multi-agent paradigm makes it possible to model and simulate those systems where the distribution of control and knowledge facilitates problem solving. Therefore, a multi-agent approach was chosen to model the system in order to 1) diagnose disturbances in the bus lines (bus delays, bus advances), 2) detect inconsistency in

positioning data sent by buses to the central regulator, 3) dynamically compute schedules, 4) monitor and process disturbances 5) simulate and choose feasible solutions. This research was part of the SATIR project done with the participation of the French Transportation Research Institute (INRETS).
Only the part related to the dynamic timetable management and management of data inconsistencies will be presented.

Timetable management involves three steps: 1) making up the theoretical timetables; 2) monitoring the network activity (modifying the timetables according to where the vehicles actually are); 3) managing the inconsistencies of the data from the sensors which locate the vehicles.
To automate these three functions, we propose two categories of agents:

1. The STOP agents, which represent the theoretical structure of the network and compute the theoretical timetables.
2. The BUS agents, which represent the dynamic part of the network. Every BUS agent is the *abstract model* of an actual vehicle running on the transportation network and reports its movements to the STOP agents.

When a vehicle passes a stop on the actual network, a warning message is sent from the BUS agent to the STOP agent concerned. The STOP agent updates its timetable by removing this vehicle from the list of vehicles due. A STOP agent which does not receive any message detects an anomaly and triggers the disturbance processing.

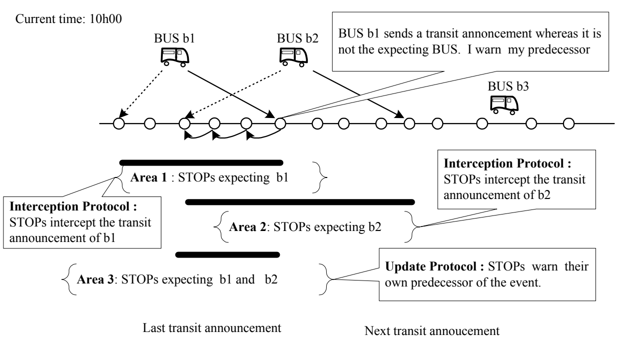

Figure 5: Inconsistencies management

One of the difficulties of timetable management concerns the management of inconsistencies which arise from the data sent by the location sensors located in built-up areas (Figure 5). Some vehicles may not be located at a significant number of stops and this may result in the triggering of false alarms. The incorrect location of a vehicle may lead to inconsistent situations with "virtual overtakings" (a vehicle is announced before the vehicle which precedes it). From the point of view of the STOP agent, there are two different problems. In the first case, there is an information defect and in the second case, there is a problem in the reception of the information. Each STOP agent concerned must be informed as soon as the vehicle is located again (in the first case, the BUS agent sends a message to a STOP agent). In the second case, it has to recognize an inconsistent situation.

The STOP agents have a filter which intercepts a warning message concerning a transit announcement that has been sent by the BUS agent whose interceptor is waiting to a STOP agent whose position is higher than that of the intercepting STOP agent (Figure 5: Interception Protocol).
The STOP interceptor thus receives a message with a reception condition concerning the reference of another STOP and it can reconstitute the context of the reception of the message. Using the context, the STOP agent is able to deduce that the vehicle was wrong by located. In this case, the content of the message enables the STOP agent to update its state and the interactional information enables the agent to modify its role in the processing of a disturbance. In this case, it is the filter which, by its function (interception of location message), determines the processing context of the message.
In the case of “virtual overtaking”, a STOP agent receives via the reception filter addressed messages (according to the identifier of the receiver) a transit announcement which the sender has sent to it. It is the comparison of the reference of the sender to the reference of the BUS agent it is waiting for that will modify its behavior (Figure 5: update protocol). In addition to taking this information into account for the update of its state, the contacted STOP agent sends a warning message to the STOP agent which precedes it in order to warn it of this event. If this preceding agent is also expecting this BUS (which is early and not correctly located), it updates its timetable and forwards the message to its own predecessor. If the STOP agent is not expecting this BUS, it will not forward the message. In this case, it is the content of the message (the reference of the sender) which allows the receiver to reconstitute the context of the interaction and to adapt its behavior.
For the same message, a transit announcement, we thus obtain an identical basic processing (the STOP agent updates its timetable) but a different reaction depending on the context of its reception:

- Message sent to the receiver by the expected sender: the local state of the network is normal.
- Message sent to the receiver by a different BUS agent: the vehicle has been "virtually" or "actually overtaken", the situation is disturbed.
- Message sent to a different receiver by the expected sender: the vehicle is wrongly located, the situation is possible "disturbed".

In summary, it is the interactional reception context of the same message which will vary the agents answer.

CONCLUSION

This paper has presented a proposal to use the environment as an interactional medium. This work represents an abstraction of our first proposal called ESAC *Environment comme Support Actif de Communication*. In the first version the problem was to define a "communication logic" enabling each agent to find its interlocutor according to the characteristics it was searching for in this agent. The new EASI proposal includes this problem and we have shown, with a toy example, how the model enables to limit the interaction cost in case of complex interaction. The proposal extends the classical view of interaction (communication organized with protocols) by allowing each agent to bind its interactional needs to the context.
In MABS, our proposition enables agents to be aware of interaction with a minimal cost. This work will be extended by modulating the interest of the interaction. The filter matches the reception condition to the context. Nevertheless some contexts (or messages) may be more important than others, which is why it may be useful for agents to modulate their interest in interaction.

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