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The User is an Agent

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ABSTRACT
Agents systems are composed of a usually great number of autonomous agents. Due to the autonomy and distribution (physical of functional) of their components, and to the multiple and dynamic interactions between them, agents systems cannot be observed at a given time as a coherent whole. Thus, these systems raise specific issues regarding the design of human-computer interfaces. In this article, we address these issues and give some clues about tractable solutions. The solutions are presented within the *Data Gardens* framework, a generic multiagent platform designed for the real-time visualization of complex systems and the interaction with them.

1. INTRODUCTION

When working with agents systems (Weiss, 1999), users are confronted to the same needs as with any other complex system (Mitchell and Sundström, 1997). On the one hand, users want to understand what is taking place in the system, which requires the design of adequate tangible representations; on the other hand, users want to be able to modify the functioning of the system, which requires the design of adequate interaction protocols. The specificity of agents systems is that they are composed of a usually great number of autonomous agents, which dynamically interact with one another in various different ways, and organize together in evolving structures. The first consequence is that they cannot be observed directly as a coherent whole (Gelernter, 1992). As in the case of natural ecosystems, only small elements of the global picture can be seen at any given time. Furthermore, only local interactions can be observed, leaving the global dynamics out of sight. The second consequence is that interaction protocols must enable actions directed towards a single agent but also potentially actions directed towards groups of agents.

As a result, traditional representation and interaction solutions have to be adapted to the context of agents systems. In this paper, we will successively address these issues, by presenting them in the unifying framework of the *Data Gardens* multi-agent platform. This platform has been designed to allow users to dynamically interact with complex systems. Or, put it more generically, to visualize complex real-time data streams in order to be able to make adequate decisions. We distinguish at least three different contexts for which it may be useful to grasp the complexity of whole systems in a way that is both natural and intuitive:

- In a scientific context, the visualization of a simulated complex system may foster the understanding of its internal dynamics by completing quantitative statistical analysis with qualitative visual analysis. As a result, it can also help design artificial systems with similar global properties.
- In an industrial context, visualization techniques are used as a means to control the functioning of real complex systems such as airplanes or nuclear plants, in order to help operators detect local or global failures. In return, it helps them to make appropriate decisions in the command of the system.
- Finally, dynamic and emergent properties of complex systems may be used in an artistic context as a source of endless novelty. The unpredictability of the system becomes a valuable property that the artist will try to retain, while at the same time constraining the evolution of the system to keep it meaningful.

After the presentation of the *Data Gardens* technical platform itself (in section 2), the paper will be organized by crossing three axis: the first axis corresponds to the functionality (sensible representation in section 3 and interaction in section 4); the second axis corresponds to the context (control/command, analysis/design, art); the third axis corresponds to the type of entities concerned with the representation and/or action (agent, group of agents).

2. THE *DATA GARDENS* PLATFORM

The main idea behind *Data Gardens* is to have societies of agents handle the retrieval and sensible representation of complex data streams. On the one hand, "information agents" retrieve data streams from different distributed sources. On the other hand, a complete society of "representation agents" is used to filter the data and organize it hierarchically. To achieve this, each of the agents is responsible for the representation of some piece of information. Not all of these agents can be represented simultaneously, so they have to "negotiate" with one another in order to decide what information is most important at a given time. As a result, some of the agents will disappear, some will group themselves together, and the remaining agents will find their place in a hierarchical social structure. The resulting visual representation will be driven by two complementary principles: the first one is to translate the social hierarchy of "representation agents" into a graphical hierarchy, most important agents being represented bigger and in a central position in the screen; the second principle is to have perceptual properties of agents reflect their nature, their activity, but also their links with other agents.

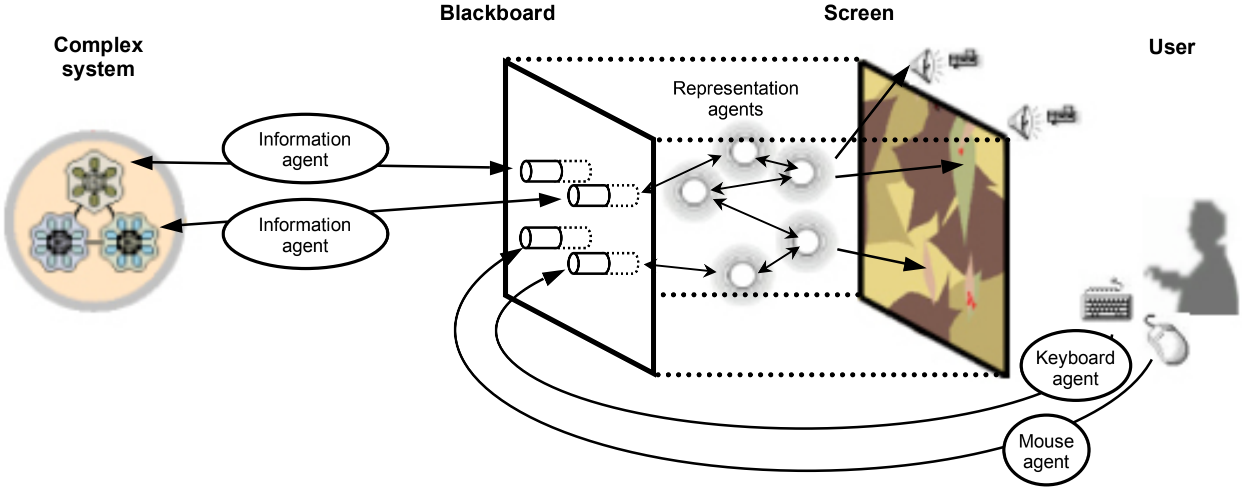


Figure 1. General architecture of the representation system. The information agents are responsible for retrieving the data describing the functioning of some complex system. The representation agents then filter the data and organize it hierarchically before presenting it to the user

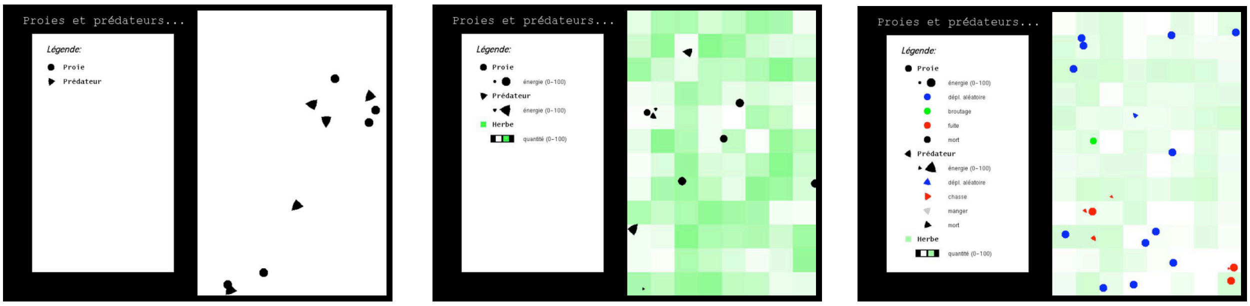
Interaction between users and the society of "representation agents" will be obtained by considering each user as a separate source of data. Therefore, an "information agent" will be responsible for the control of a user, examining its actions through the keyboard or mouse, or its physiological reactions through eyes-tracking techniques, or heart rate sensors. In a sense, the user becomes an agent that has the ability to interact with other virtual agents. Therefore, he becomes able to explore an agents system by testing the reaction of the system to given perturbations. Or, he can modify the representation process by modifying the behavior of agents or the priorities attached to the data.

3. VISUALIZATION OF AGENTS SYSTEMS

The issue of visualization strongly depends on the function that is desired. If what we need is to *control* the functioning of a system, then the aim is to give a synthetic view of this system and to highlight dysfunctions as they appear. If what we need is to *understand* the functioning of the system, then the aim is to display the state of the agents composing the system and the interactions between them. These two approaches for the visualization of agents systems are complementary and may be used alternatively when "debugging" the functioning of a system (Giroux et al., 1994; Hart et al., 1997; Ndumu et al., 1999). We will now develop this aspect somewhat further by detailing possible visualization strategies for a "toy" multiagent system of preys and predators. In this system, predators try to trap preys, but a lonely predator can't succeed in it. Thus, when a predator detects a prey, it will call out other predators for help.

3.1 Visualization of agents

The first step in building a visual representation for such a system is to check what elements are important for the understanding of the evolution of the system. Position of preys and predators is naturally of crucial importance and it is equally important to be able to distinguish between the ones and the others. This is what we would call *identification* and *positioning* of agents in the system and it corresponds to figure 2.a. The position in the picture corresponds to the position of the agents in the environment and the shape corresponds to the type of agent (discs for preys, triangles for predators, rectangles for grass patches).



(a) (b) (c)

Figure 2. Different steps in the visualization of a prey-predator system. (a) identification and positioning of the agents (b) visualization of the internal state of the agents (c) visualization of the current activity of the agents;

The second step is to identify the *internal state* of the agents. Preys and predators for example are characterized by their level of energy. Preys gain in energy by eating grass, which continually regenerates. Predators gain in energy by catching and eating preys. Figure 2.b shows an example of representation derived from the previous one that takes this parameter into consideration: the color of grass patches and the size of preys and predators are in direct ratio to the level of energy.

The third step is to identify what the agents are presently doing. For preys as for predators, one can distinguish three types of behaviors: rest or random movement, feeding, and hunting behaviors. Colors may be used to differentiate between these various behaviors. Figure 2.c shows an example illustrating this strategy with four colors used (one for each behavior, plus one when the agent is dead).

3.2 Visualization of interactions and groups

More than agents, it is important to visualize interactions between them. In the example, this can be achieved by taking advantage of properties of perception (Arnheim, 1974). By giving identical colors to hunting predators and to fleeing preys, or by orienting the hunting triangles towards the fleeing discs, a link is visually established between the predator end its prey. Movements are also very efficient to display links between the shapes.

Finally, the dynamic creation and disappearance of groups of agents, and more generally global structures, is potentially important to visualize. The creation of hunting groups by predators may thus be visualized by giving a distinctive color to all the agent of a same group. Or we can consider this group as a new entity and replace the individual predators by a single hunting entity synthesizing the information of the different agents.

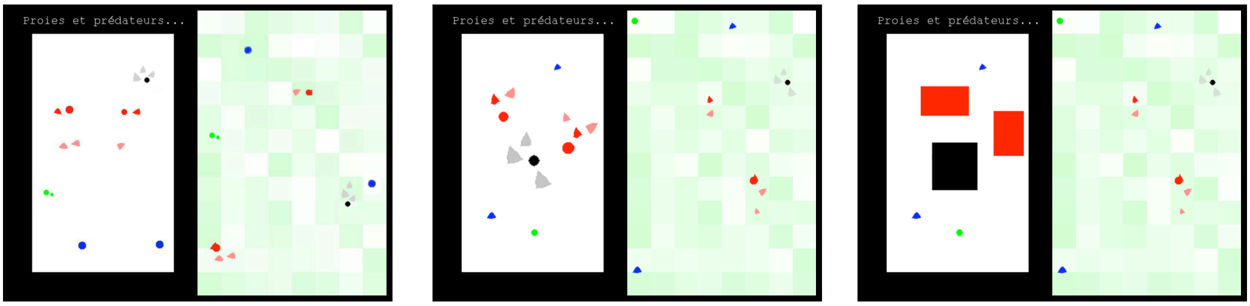
3.3 Rearranging the visual representation hierarchically

More generally, it may be interesting to completely rearrange the representation in order to display the most important events occurring in the system. To achieve this hierarchical organization of the representation, several strategies can be used.

A first strategy is to design the visual representation of agents so as to have important events become immediately perceptible, for example by using red tints when something important has occurred. Basically, each of the graphical means of visual representation (shape, size, color) can be used to show off specific aspects of the system: a distinct shape, a big size or a contrasted color are different means to enhance the perception of an agent.

A second strategy is to abandon the strict correlation that we used up to now between the position of an agent in the system and its position in the representation, or between agents and their corresponding shapes. In the first case, one can imagine to have the shapes rearranged so that the most important ones are placed in remarkable positions such as the top (figure 3.a) or the center of the screen (3.b). In the second case, the aim is to make the structure of the system more apparent by grouping agents that share common characteristics (figure 3.c).

Position, shape, size and color are different graphical ways to visualize such things as the identity of the agents and their situation within the system, their internal state and their behaviors, the creation and disappearance of interactions and global structures. These graphical solutions are not exclusive of other more classical ones such as text, curves, graphs, but they were useful for the presentation of the example. What is constant however is that agents, interactions and structures must be dynamically displayed so that an interaction becomes possible with a user.



(a) (b) (c)

Figure 3. Different forms of hierarchical representation of a prey-predator system. For each picture, the right view corresponds to figure 2.c. The left view corresponds to: (a) most important elements on top (b) most important elements in the center (c) use of "group" entities

4. INTERACTION WITH AGENTS SYSTEMS

To achieve this interaction with a user, the basic idea is to consider that he is an agent in much the same way as other agents. In a sense, this is compliant with the definition of agents as autonomous entities with social abilities, perception and reactivity to their environment, and pro-activeness, i.e. with goal-directed behaviors. Technically speaking, we explained how this might be obtained within our framework. Conceptually, this implies that there should be a common environment comprising both human and artificial agents, and a common interaction space where both types of agents may be in contact.

4.1 A common interaction space

Two elements are required to represent complex systems within the *Data Gardens* platform. Firstly, *information agents* retrieve the necessary data to describe the functioning of the system (and take commands in direction of the system); secondly, *representation agents* make use of the data to build a coherent visual representation of the system. The principle is identical as far as human users are concerned: information agents (mouse and keyboard agents in figure 1) retrieve information about the commands of the user; then, representation agents enable the user to be present within the representation space, next to the representation of the agents system that he wants to interact with. These representation agents are like avatars except that we can have simultaneously several representation agents for a single user.

To take a basic example, one can imagine that the avatar of a user will continually check the information given by the mouse agent and will react accordingly. As a first thing, it will make its position correspond to the position of the mouse, enabling the user to move within the interaction space. Then, he will listen to mouse-click events so as to take predefined actions when the user clicks with the mouse.

4.2 Different interaction strategies

One can imagine several principles of action, directed towards a single agent or towards groups of agents.

The first possibility is to have a predetermined action directed towards the agent that is closest to the user's avatar. To achieve this, the avatar will have to determine which agent is closest and then interact with it. In the prey-predator system, we may want to kill some of the predators or some of the preys to see how the other population will adapt to this new situation. In this case, we simply need a "killing avatar", whose action will be to kill the agent closest to the mouse location when the user clicks on a button. In the same spirit, we may also desire to catch a prey or predator and see what happens when it comes within reach of an agent of the other population. In this case, what we need is a "grabbing avatar", whose action will be to take control of another agent's position as long as the user holds the button down.

The second possibility is to have a predetermined action directed towards a whole set of agents. For example, we can imagine taking actions that should affect all the agents within a given range. If we want to water the grass, then the grass patches should receive quantities in inverse ratio to their distance from the avatar. What we need is a "watering-pot avatar", whose action is to propagate a "watering-signal" as long as the user holds the button down.

All of the examples that we give show reactive modes of interaction because the agents considered have very reactive modes of functioning. The principles however are very generic and may of course be applied to linguistic interactions with cognitive agents as well.

5. CONCLUSION

We tried to address the issue of the interaction with agents system in a generic, yet applied way. To this end, we presented an example that is of course a very simplified vision of the actual complexity of agents systems, but that puts into light some of the basic difficulties raised by these systems. The solutions that we propose are based upon the generic *Data Gardens* framework, more than upon specific visualization or interaction means. In this framework, other visualization means may be used and other interaction modes may be imagined. Furthermore, multiple users may be involved in the interaction with a single agents system, or a single user may be able to interact simultaneously with multiple agents system.

Interestingly enough, this approach may be extended to the design of "classical" computer-human interfaces. Indeed, we talked about *avatars* when we addressed the issue of the interaction with agents. We may have talked of *active tools* instead, which the user could choose from to achieve specific tasks. The difference with classical tools is that these active tools may be assigned specific goals that they will try to reach, responding to users in a way that would be both reactive *and* pro-active. This kind of tools would thus be able to take the current and past contexts into account when acting on behalf of the user, they would be more autonomous in the realization of a task, and they could dynamically adapt when the context evolves. In our opinion, these are properties that traditional computer-human interfaces lack and that should be developed in the future.

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