An adaptive system to control robots: ontology distribution and treatment

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Abstract: Computer science evolves ever more quickly towards autonomy: self-managing, self-configuring, or self-optimizing. This is an extreme view of automation. These features are crucial for the next generation of robots and software to help developing new tools. For these ambitious aims, there are different approaches such as datamining, expert systems, complex systems among many. Here, a multi-agent system to distribute ontology to control robots is presented. This project is developed with the Oz/Mozart system and a prototype is used to produce preliminary experiments. We present a method and its implementation for ontology distribution. This processing creates a scene description (a context in an environment) and makes a decision to follow a goal defined by different parameters.

Key–Words: Multiagent system, intention, emotion, behavior, morphology, ontology, adaptive system, autonomy, robots.

1 Introduction

Complex systems and adaptive systems have an ever increasing importance in computer science particulary in distributed programming, multi-agent systems and microkernel development. All these themes help to continue task automation with an extreme view: mimicking human behavior.

This paper presents one part of a global project. The goal is to create a software entity[1] to control a hardware entity[2] with incubation software[3] or to provide specific experiences associated with specific knowledge.

[1]In the next sections of the paper, this entity is called an artificial brain. It is not a physically copy of a brain but a model which mimics semantic treatment processing.

[2]Robots, computers ...

[3]This is the training time, specific learning, with objects, movements and parallel processing.

2 Global project

In this section, an overview of the global project is presented to situate the paper in the larger context. The ontology distribution of the artificial brain is examined.

The initial project is described by Cardon in [5] and [6] and by Camus and El Khadi in [4]. The project entitled PALOMA creates an autonomous entity evolving in an unstable environment for multiple robots. There are two essential sections in PALOMA:

1. The creation of the software entity similar to an adaptive system as presented in [7].
2. The creation of the artificial incubation that trains the software entity for a specific mission.

The first section is composed of two elements:

- the body of the robot (or any machine)
- the brain of the robot (or any machine). The brain is represented by an adaptive system associated with an ontology.

The second section is composed of an environment generated by a specific engine to build several contexts (scenes) with its associated objects and actions.

3 Entity description

In our case, an entity is described as a machine with a body and an artificial brain which is not embedded for performance reasons as shown in Figure 1. This approach follows that of Damasio in [8]. Contrary to Descartes in [9] who states that the mind is completely separate from the body, the body and mind process in synergy. It is only with the body that the mind can treat different information in an environment.

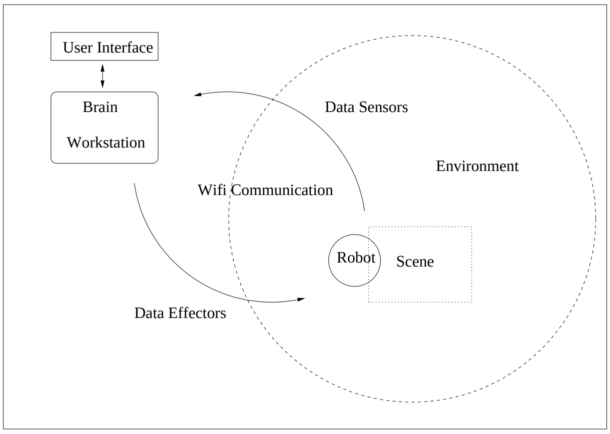

Figure 1: Brain workstation and its environment

The artificial brain is linked to sensitive sensors, effectors, position sensors, camera and other devices. All data is processed at the same time to organize information and make an interpretation. Five processing levels for decision-making in an instable environment as described in [3] are considered: represent a contextual situation, direct attention to particular elements (objects or actions) and feel emotions based on these elements. Also, verify if these elements can be used to achieve a goal, build behavior action plans and react to feedback. All these levels form a systemic loop described by:

sensors ⟶ **representation** ⟶ **interpretation** ⟶ **action plan** ⟶ **effectors** ⟶ **sensors**.

Notice that the entity is continuously processing.

4 Genericity and processing

The system is adaptive and can be used not only for different robots but also for all algorithm problems needing decision-making. There are several application cases. A small, yet interesting set of applications in section 10 are considered. The system parameters are as follows: sensors, effectors, the ontology, the experience of the system, the number of agents for each unit of knowledge, a coefficient of agent activation which is proportional to the power of the CPU, frequency for morphology agents message sending, frequency for analysis agents message sending and frequency for structure agents message sending.

An ontology and an experience can be independent of the hardware. In fact, when the knowledge is linked to a hardware element, there is a problem; treatment of knowledge data is compromised. Since it is not an embedded system, all processing is treated on a remote computer. Communication between the hardware and the artificial brain is continuous. Figure 2 demonstrates that when the system is executed for the first time, the hardware sends its list of sensors and effectors to the remote machine. After this happens, the systemic loop is valid and the hardware entity can generate "thoughts."

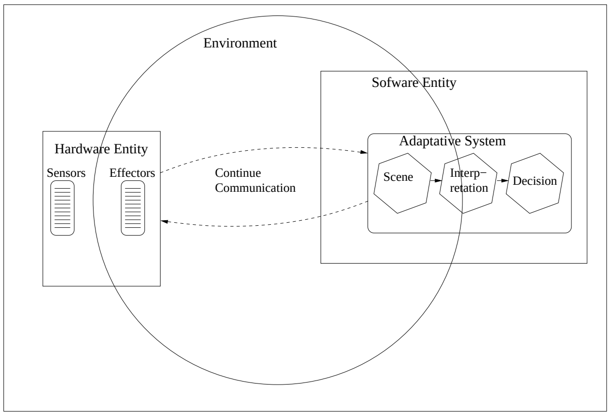

Figure 2: Communication between the hardware entity and the software entity. The hardware entity sends the list of sensors and effectors during the first connection. After this, there is continuous communication.

A sensor and an effector have a fixed architecture, hardware with a set of allowed values or a flux such as a video flux. After the initialization of all sensors and effectors, values can be replaced by a string such as "caress" for the sensor on the head of the Aibo or "ball" if the robot recognizes a ball in the environment.

5 Ontology

Ontology, a specification of a conceptualization as defined by T. R. Gruber in [10], is the most important element in the system. Without knowledge, the system does not realize that it exists. The system is unable to recognize the object in the current scene and it cannot update its memory, so it cannot make decisions. Ontology can be general or specific to in an important mission as in the case of an Unmanned Air Vehicle. There are two crucial sections for ontology processing: ontology description and ontology treatment.

5.1 Description

In theory, ontology is described as a tri-dimensional graph with specific classifications. These classifications give information on the origins of this knowledge. Currently, there are nine elements of classification but it is not a fixed number. It can evolve with ontology updating[4], after an action, a thought or a specific scene. The different elements are as follows:

- Capacities: all the physical capacities of the hardware entity, i.e., the sensors and effectors.
- Objects: simple or composed objects such as a cube, a sphere, a keyboard, a coat, a table, or chair. An object in general, a thing according to Heidegger in [11].
- Verbs: currently, verbs in general. But this section will evolve towards a more precise classification with active or passive verbs.
- Colors: base colors and mixed colors.
- State: the state of the entity where there is a strong link with the verb for several elements such as “to tire” or “to sleep.”
- People: all persons that the entity can remember.
- Space: this section establishes where the entity is located or where it is compared to other specific elements in the ontology.
- Simple emotions: basic emotions such as pleasure or pain as well as many others.
- Mixed emotions: emotions using basic emotions such as love which includes pleasure, joy, pain. This list is not exhaustive.

All these elements can evolve. The corresponding graph is shown in the figure 3.

[4] It is a systemic loop, the system is never halted, so, all actions and thoughts are saved in the ontology.

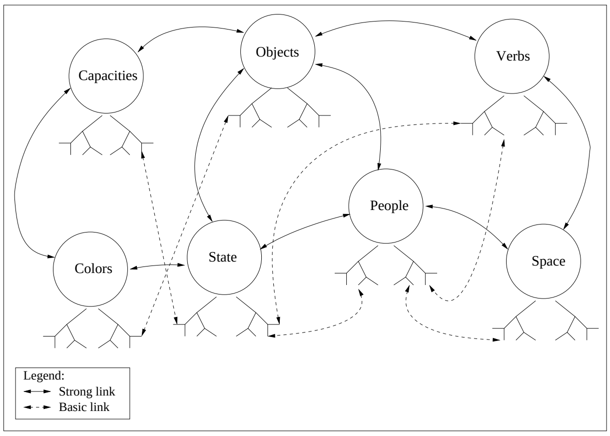

Figure 3: The ontology is implemented with a graph classifying all elements present in the base. Here, all links are not visible as there are too many bonds. This graph could be modified dynamically during processing of the systemic loop.

5.2 Treatment

Ontology is distributed in a multi-agent system. Each agent can be excited by data which is transmitted to the multi-agent system. A description of the system is presented in [3]. For each unit of knowledge, a role is generated for each agent. Each role has a rate similar to a fuzzy logic. For example, a role “ball” could have five agents with different recognition rates. Data arrives from the sensors to pass to all agents present in the system. If the data matches with the agent knowledge, the agent becomes active and alerts the other agents in its acquaintance group. We can imagine a tri-dimensional matrix with a strong (or not) link between each element of matrix shown in figure 4 in a two dimensional view.

Figure 5 shows the activity of several agents in the system. It is interesting to see that two agents with the same role[5] do not have the same value. For example, the system wonders if it sees a chair in the office but it is not sure. With time, it will see this chair.

6 The role of emotions

Emotion plays a role in human decision-making as explained by Bechara, Damasio H. and Damasio A.R. in [1]. This is an interesting discovery for the theme of decision and optimization in computer science. This explanation is supported by cognition scientists such as Lerner and Keltner [14] with a paper on a model

[5] A role can be considered as an action to be applied to a specific recognition

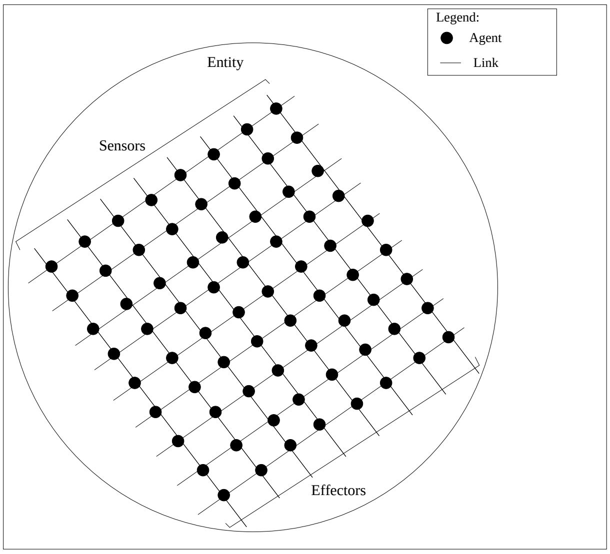

Figure 4: A two dimensional view of the agent matrix. Each agent manages one unit of knowledge. The unit of knowledge forms the ontology of the system. All the links between agents are not presented here. Each agent is linked with the others. To ensure a quick response in an unstable environment, all the agents are mapped in the memory.

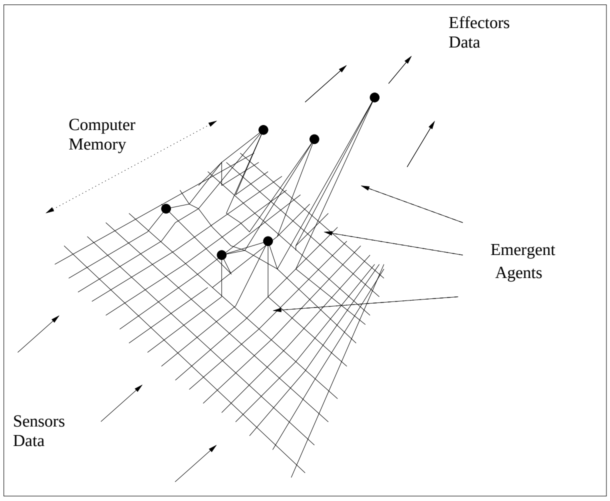

Figure 5: Here, an emergence of agents according to data coming from sensors is displayed. With this method, it is possible, at any moment, to have a description of the current scene, the environmental context composition, i.e., when, where, what. All agents are mapped in memory.

with specific emotions influencing the judgement and choice of human decision-making. We agree with this point of view, but in this project, there is a difference between the description and the treatment of the emotion. Here, the same questions arise as in section 5: how the emotion is described in the artificial brain and how it is treated.

6.1 Description

During a lifetime, knowledge evolves and understanding increases with additional behaviors, sensations, and emotions. Before the age of ten, a person will feel something such as happiness but there are also other emotions and it may be difficult to describe them. With experience and continuous learning, a name is found and, with this name, the emotion can be recognized. For Lafortune, in [12], emotional intelligence exists. An emotion can be composed of other emotions. There is a classification of emotions as Larivey explained in [13]. In this classification, there are four principal elements:

1. The simple emotions: desire, affection, excitation, joy, pleasure, pain and fear to name a few.
2. The mixed emotions: emotional experiences with several simple emotions. The result is love, passion, shame, guilt and countless others.
3. The suppressed emotions: a physical experience pushing back an emotional experience. The result is distress, anxiety, panic, nervousness or other discomforts.
4. The pseudo-emotions: a metaphor to describe reality: they are not really emotions. There are nice, coping, sympathy, timidness, compassion, confusion. This list is not exhaustive.

This classification is used here. Consider that an emotion is knowledge, with a name which represents an interpretation of several data in the nervous system. The emotion is described in the ontology as represented in the graph in the section 5.1. A new graph is attached to the ontology graph: the emotion graph, as shown in 6, which will be included in the ontology graph during the processing of the systemic loop[6]. With large amounts of knowledge, this graph is very complex and increasingly complex with experience. The power of the system is directly linked to the power of the computer.

[6] There is no difference between units of knowledge. It is easier for a human to have a classification to know what is saved in the ontology, but the system doesn't recognize the difference.

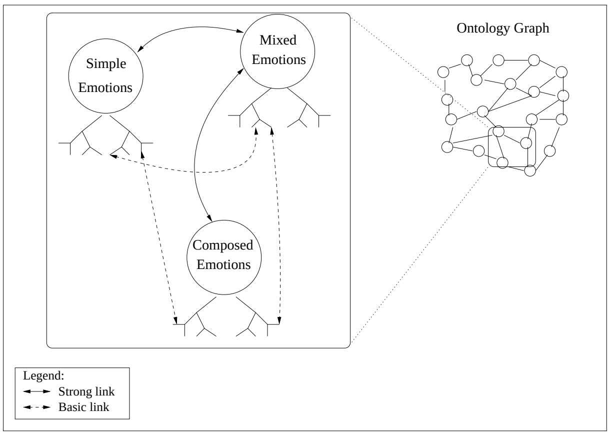

Figure 6: The emotion graph which will attach to the ontology graph. It is only a classification to facilitate the treatment of the knowledge by a human because the system did not recognize the difference if it is not in the pathology. The pathology of the system can be described with words.

6.2 Treatment

Emotion treatment is implemented as knowledge in the ontology. Each known emotion is distributed in the multi-agent system[7] and treated as knowledge, a capacity to communicate with physical capacities or mental capacities. The global definition of an emotion can be easily described in a general context. However, in a practical case study, it is more difficult to define. In fact, this description is linked to the experience and the learning, and that is the reason a culture is crucial in any education. A section concerning emotion in a multi-agent system can be observed in Figure 7. For each system using artificial brain, with the same sensors and effectors, it is interesting to note that the behavior can be totally different if the robots' experience and pathologies are not the same.

Using this processing method to configure the system with a particular pathology is easy. A person may have developed fear of stress more easily in a specific pathology. It is possible to do the same thing with the artificial brain. More importance can be given to a section of the system which treats the element "fear" for example with an increase in the number of agents. All emotions can be accentuated in the system to transform them into an emotional system.

[7] The entire system is a massive multi-agent system. As the ontology increases, the number of agents increases. Currently, more than one thousand agents have been tested.

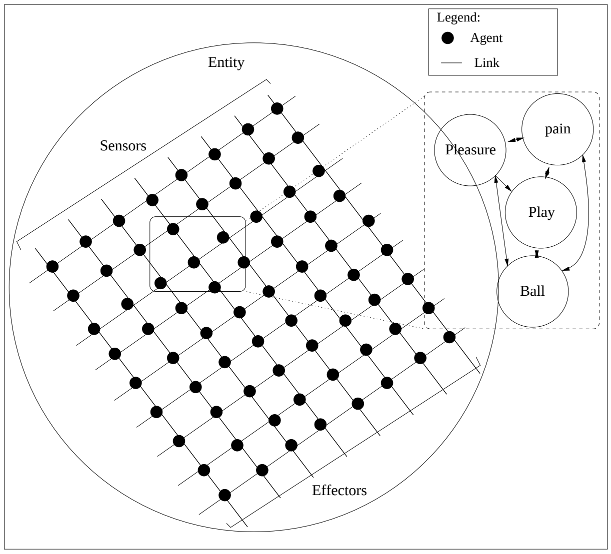

Figure 7: A section with different links with emotions, verbs and objects. With much experience, a lot of elements in the ontology can be linked. Here, it is pleasant for the system to play ball, but pain is also a possible hypothesis. If the size of the section changes, a specific painful action from the past which may have been accident with a ball, or another painful event may be discovered.

7 Control

Control is crucial for the artificial brain. In section 5 and 6, we have explained that there is an excitement of agents with the passing data. All agents in the system are treated at the same time, so when several agents activate themselves simultaneously, a geometrical form is created. The phenomenon is called morphology and has been discovered by Thom and presented in [16], it is a special branch of dynamical systems theory. To control the multi-agent system, we rely on the Campagne model presented in [2]. This model is an adaptation of Thom's morphology [17] for multi-agent systems. Notice that this model has been adapted for asynchronous communication.

The morphology role is to direct the system towards a specific form to achieve a goal. There is a continuous communication between agents and morphology. Morphology matches all the time if the goal direction is respected. Morphology increases or decreases the importance of an agent group.

8 Multi-Agent implementation: adaptive system creation

The distribution method of ontology in theory in the multi-agent system in section 5 and 6 has already been presented. This system is described as an adaptive system, but an explaination is needed concerning what is adaptive and how this system is adaptive. In this section, the architecture and the implementation method of an agent in the system are defined.

All agents in the system share a specific architecture. Figure 8 shows a description of an agent. Each agent has: a communication API, a knowledge base, an inference engine, a state, intentions and goals.

Intention and goals are described Figure 9. There is a general intention stack which is synchronized with the goals to know which will be treated by the agent in what order to achieve each goal. These features manage all cases in the system with an abstraction level for the communication API.

After this presentation, an agent and a role (explained in section 5.2) are described as a class of a programming language. When a new instance of a class "agent" is created, a new instance of a class "role" and eight threads to compose the communication API are built: a configuration thread to dynamically modify a set of parameters, a multiplexer thread to manage all messages treated in the system called the input thread, a delay thread to measure the frequency of the communication in the output, a filter to treat all messages before transmission to the role, an output thread to send composed messages, an input thread for the role, an output thread for the role and a configuration thread for the role. All agents in the system are autonomous. The system adapts itself with parameter modifications, a sensor, an effector, or the ontology. An agent is autonomous and an autonomous entity is an adaptive system.

9 Experiment

This experiment uses an Aibo ERS-7 by Sony at the L.E.R.I.A. laboratory with these parameters: a tiny ontology (eleven mega-octets), more than one thousand agents evaluating more than seven thousands threads in the system, an unlimited activation coefficient[8], a simple goal: to have pleasure (play, sleep, listen music) and not to have dissatisfaction (pain for example), a morphology frequency of 3 seconds, an analyse frequency of 10 seconds and an agent frequency of 10 seconds.

[8]The agent activation has a strong link with the system experience.

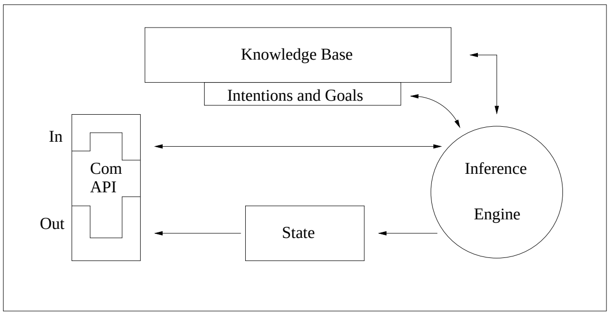

Figure 8: An agent has a fixed architecture in the system. Agents communicate between each other using message passing. This method is presented after the architecture.

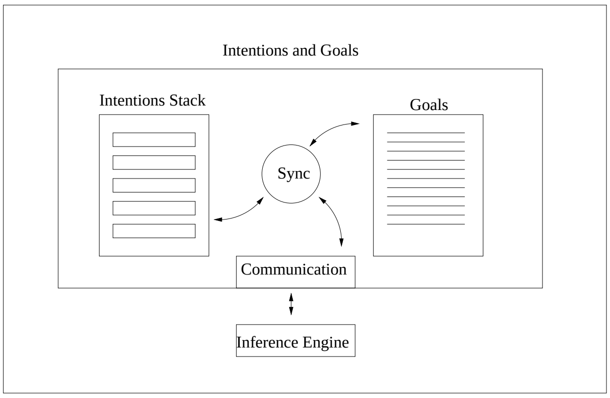

Figure 9: An agent has a role to play in the system. To achieve this role, an agent has a list of goals and measures the priority of each goal.

There are four phases for data interpretation:

1. Data transit in the multi-agent system. During this phase, it is impossible for a human to interpret system behavior.

2. Information interpretation by the system to create an emerging idea with morphology as explained in the section 7.

3. Choice of a specific form with morphology. After this choice, specific roles will emerge.

4. Creation of an action plan with the emerging knowledge.

Figure 10 and 11 show the focal point of the system in real-time, the robot's current thoughts with a specific ontology, a specific experience and a particular scene in the environment. These thoughts evolve in a timeline. They depend on different links between roles (the past experience of the robot, the ontology). An emergence of several roles in the multi-agent system are built with an asynchronous communication. This element corresponds to section two of the data interpretation. The frequency parameters presented in section 4 have a strong link with the focal point. The more the difference between morphology frequency and agent frequency is increased, the more the density of the focal point is increased, and the "thought" becomes more complex.

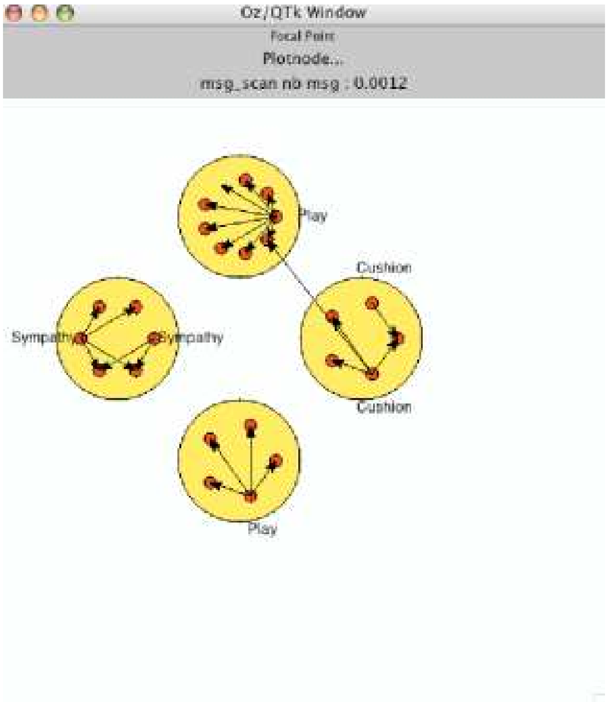

Figure 10: Here, the current idea of the system is displayed. This element depends directly on the experience and the knowledge of the system. This idea evolves.

As the robot notices certain elements in the scene: a ball, the color pink, it feels sympathy. All information is treated by the system. In Figure 10 and 11, the emergent aspects are play and ball. This can be interpreted by the fact that the robot may want to play ball because he would like to feel pleasure. These charts don't show all the different links between agents but the degree of importance of one or several units of knowledge for a scene. Knowledge and experiences are all processed in synergy.

After knowledge analysis, the system can make a decision to act on the environment. This decision is a synchronization between physical capacities and emergent knowledge. With the current idea and the goal of the system, the experience provides the appropriate behavior to move towards a specific objective to achieve a goal. With this method, an eleven mega-octets or ten giga-octets ontology, the action will be immediately processed.

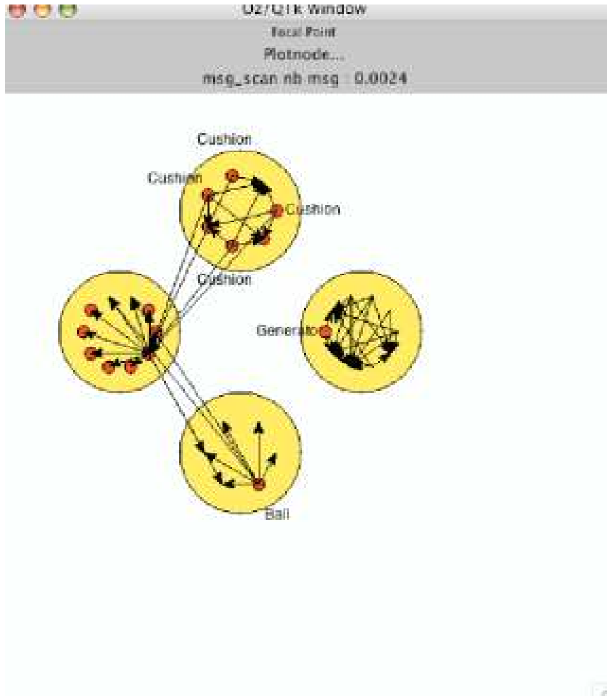

Figure 11: Later current idea of the system. In Figure 10, the idea of play emerges so, here, it has a thought for a ball.

With the employed method and with an ontology of eleven mega-octet or an ontology of ten giga-octet, the action will be immediately processed.

10 Future

10.1 Modeling

The work described in this paper is a way to build an adaptive system generating intentional behavior. The system must be tested with a larger ontology (greater than 100 mega and after, greater than 500 mega), therefore with an increasing number of agents (ten thousand or more greater). We have at our disposal eight hundred computers to distribute all threads. With this distribution, more than eight hundred thousand agents could be reached. The development system Oz/Mozart[15] allows us to simplify the distribution.

System modeling is of great importance. After ontology distribution, scene description, system direction and a decision is made, there are many questions. How are different goals synchronized ? how are goals priorities dynamically changed ? How is ontology updated in real-time? How are knowledge, emotion, and decision-making correctly synchronized? How is new knowledge saved and classified automatically in the ontology? This list is not exhaustive; the research continues.

10.2 Domains

Domains are important. Currently, we use an aibo ERS-7, but the system can use other hardware entities such as an Unmanned Air Vehicle, a car or a spacecraft. This system can also be used for user problems with similarity between sensors and the graphic user interfaces and effectors with actions on a database for example.

11 Conclusion

Adaptive and complex systems are increasinly important in computer science research. Industry needs generic and adaptation tools to gain flexibility and to have increase profits with decreased costs. Understanding human behavior is crucial to continue task automation.

In this paper, we present an artificial brain created with an adaptive system. All unit of knowledge and emotions of the system and links between unit of knowledge or emotions, are described in an ontology. Ontology is distributed in an adaptive system which is created with a multi-agent system. Environmental information is captured by sensors. Actions on the environment are processed by effectors. All actions are immediately evaluated in the systemic loop. Experiments show that the system can think and act simultaneously to achieve a goal.

This system can be used for robots, operating systems, or software with an association between sensors and a graphical user interface. There are many application cases in science and in industry. Tests with a large number of agents (more 100 000) must be performed to verify durability on a more powerful computer. Currently, all tests are processed with an Aibo ERS-7 by Sony. It will be interesting to try other domains such as game theory, language learning or spacecraft autonomy. We believe that only the parameters have to be changed to test these cases.

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