Towards Morphology Study of Massive Multi-Agent System to Represent Robot States

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Abstract. We are interested in developing notion of artificial emotion for a robot which are inspired from biological emotions as described by A. Damasio [1]. Artificial emotions are considered as a reaction of an artificial organism to the environment, based on its internal states. The work presented here, is based on notion of Morphology of Massive Multi-agents System originally described by Alain Cardon [2, 3]. Morphology is understood as representing the global state of Multi-agent System as shape in geometrical space. This notion is close to the notion of phase space in physics. We propose to investigate the relation between a behavior of a robot and the morphological representation of its current state by associating Massive multi-agent systems to a couple of sensors of the robot.

1 Introduction

The study of Multi-agent systems has started with limited number of agents, mainly because of the capacity of computers. Since this limitation has been reduced with the advent of new technology, it is now possible to build new large scale systems. Two ways can be chosen to model agents, one is to build high complex cognitive agents, and the other is to build agents with low level behaviors and to study multi-agent systems with a large number of agents. It is on that second aspect we are interested in. The research interest about the analysis and the control of such massive multi-agent systems has increased this last decade in many field of research. However methods or systems are less frequently proposed. Some approaches have been presented in order to control multi-agent systems based on "Manual tuning", emergence based theory, or genetic algorithms. If manual tuning is suitable to control or to analyze the behavior of couple of agents, it is almost impossible to apply it to massive multi-agent systems. Emergence based theories describe a control from bottom (agents) to top (system). By modifying the agents' cooperative behaviors to resolve local conflicts, one expects that the system will get the proper global behavior [4]. It seems to be difficult in some cases to associate local behavior to global behavior, especially if we consider massive multi-agent systems composed by large diversity of agents. The genetic approach was recently proposed to explore a large space of cooperative possibilities among agents [5]. This interesting approach proposes a way to control the global behavior using fitness value. However it is difficult to understand the relationship between fitness and overall behavior that emerge from the systems.

Another approach using concept of morphology originally describe by [2] have been proposed in order to analyze and to control and massive multi-agent systems [6]. The underlying idea is to describe state of agent organization, by projecting the state of the agent organization in an abstract geometrical space from various measurements made at the agent level. This projection is called morphology. The main system hypothesis is to consider that the shapes representing the system's states are correlated to the system's behavior. It has been shown that using this architecture, it is possible to control the population of an organization. This approach shows the possibility to perform an analysis of organizations from top (system) to bottom (agents) in order to control global behavior.

Towards description of system state

The research field of analysis and controlling massive multi-agent system is part of larger complex systems study, like robot control, chaotic systems in physics, biological sciences, or emergence phenomenon in social and economic sciences.

1. Emergent behavior systems

The study of chaos properties has been reserved for a long time to the analysis of physics and natural systems. Recently, some researches in robotics tend to use chaos model in the analysis of emergent behavior [7]. The goal of such systems is to understand the role that can play chaos in the emergence of behaviors and what kind of control it can be applied on it. This kind of research is oriented to behavior emergence from a robot on which effectors are coupled with chaotic systems. However this approach led to the necessity to be able to detect and classify these behaviors.

Another field in robotics research is exploring the dynamics of system-environment interaction, to achieve different types of locomotion [8]. This system based on body dynamics proposes a way to build embodied adaptive behavior. The underlying idea is to build embodied responsive system in order to adapt the physical system's behavior to the modification of the environment, without any algorithmic or high level of symbolic control. The system presented is about the adaptation of a dog's locomotion state (walking, running, passing through obstacles). It shows the possibility to build fast adaptive behavior with relatively simple mechanical system based on springs. However this system, by definition, lacks of getting a way to analyze itself, and representing its actual states. Neural network systems have been coupled to sensors in order to try to detect different states. The constraint is that it requires an a priori knowledge of possible states of the body. We think that such embodied system is interesting because it allows, like for chaotic control based systems, a large scale of possibilities of emergent behaviors. To represent internal state of such robot, one needs to consider the possibility to detect and explore new possible states that may not be predictable.

2. Internal states models

The study of emergence of community behavior inside an organization and the way to classify different types of homogenous behavior is closely associated to the research field of physics, chemistry, social science or economics. Some studies have been done on these fields, trying to understand and provide a control of complex organizations by analyzing global behavior in order to control local behaviors. This kind of approach is particularly used in field of economic sciences.

In an more surprising field such as biological science, new approach are dealing with concept of emergence inside organizational system. These concepts appear especially in domain of emotion study. Biologists such A.Damasio [1] have proposed a new definition of emotions based mainly on reactive behaviors built from internal state representations. That global internal state representation of the organism is the result of the competition between different local representations with different sensitivities. The resulting emergent representation is associated to a special type of response behavior. In such concept, the internal state, and its representation highly depends on the sensor capabilities and the architecture of the body. This supposed that emotional states are unique for each body morphology.

We think that such internal state architecture is similar to multi-agent system architecture. The states of each agent, and, in a higher level, to each organisation of agents describe a representation of the current environment with different sensitivities. The global state of the organization as result of competitions and negotiations between agents and groups of agent can be associated to a specific behavior.

Description of the general approach

1. Hypothesis

The work presented in this paper is a part of a larger system originally describe by A. Cardon. This underlying idea of that system is based on the correlation of micro-level behavior (agents) and macro-level behavior (organization). The basic hypothesis is that the shapes of organization should be correlated to the system's behaviors. Detailed description can be found in [1, 2].

2. General description

The general architecture of the system is composed by three different organizations (fig. 1) : the aspectual organization, sensitive to the external environment; the morphological organization which describe the state of aspectual environment in geometrical space; and the analysis organization that control aspectual organization using description done by the morphological organization. This analysis organization contains general trend of the system given by the system designer.

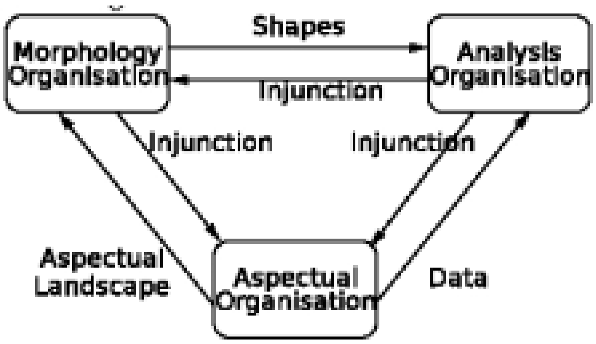


Figure 1: The general architecture composed by the three organizations.

3. Aspectual organization

The aspectual organization, containing many Aspectual agents sensitive to different types of external environment information, represents phenomena that we want to study. The term of "Aspectual agent" comes from the original agentification methods proposed in [1, 2].

Each aspectual agent, using information about their local environment, computes a value or a set of value that is called "aspectual vector", as they run. This set of value describes the state of the agent, and its current activity. By definition, the aspectual vector is closely related to the structure of each agent.

4. Morphological organization

The whole collection of aspectual vector computed by aspectual agent forms what is called the aspectual landscape of the aspectual organization. The morphological organization will analyze this set of aspectual vectors in the geometrical way.

Morphological agents attempt to describe what it is happening in the aspectual organization in order to classify different possible states of the organization. The morphological organization doesn’t take in account the ontology previously defined for the aspectual agents, that means we do not use any semantics in the morphological space.

The morphology analysis is only concerned by the activities and the state of the agents. Ideally the morphology should point out structures, shapes, similarities, opposition, recurrent features....The tools used for representing morphology have no restriction and can be as well histograms, distances, network connectivity...

However in order to be able to control organization, one must consider that aspectual measure should have reciprocal. The reciprocal is a function that modifies the aspectual agent behavior according to some target value expected, so that the agents will conform to that target value.

5. Analysis organization

The purpose of the analysis organization is to correlate the overall aspectual organization's behavior to the shapes revealed by the morphological organization.

The analysis agents use the morphological description to examine the aspectual organization and to orientate the system accordingly to some generic guidelines instructed by the designer. For example the global variable X of the system should be around value Y. This is achieved by classifying and learning the morphology: as the system runs, typical shapes are correlated to the system's behavior and categorized appropriately.

In a second step, as the system evolves in time, it should be possible to associate trajectories in the morphological space with the behavior of the system. Trajectories can be understood as successions of shapes. This property should allow us to predict the global behavior of the aspectual organization.

Analysis organization is important in a sense that it provides a kind of symbolism of the overall system state, through the aspectual and the morphological organization. By giving feedback and control to the aspectual organization, its role is to influence the aspectual organization following the designer's guidelines. It can also select appropriate shapes learned from the system's past activities, and tell the morphological agents that this particular shape would be more appropriate than the current shape.

6. Our proposal

As said previously, it has been demonstrated the property of this architecture to get self analyzed [6]. We proposed in this paper to study the behavior of aspectual organizations when aspectual agents are linked to sensors of robot. The preliminary goal is to link agents with sensors, to build Aspectual organization regarding the physical morphology of the robot and to study what kind of morphologies we get, in order to provide a robot state analysis by analysis organization. We focus the study on the morphology, and on the architecture of aspectual organization on AIBO robot.

Description of Massive multi-agent architecture used

In this section we describe the overall behavior of the multi-agent systems used in the three organizations describe previously. We use the same generic architecture for each multi-agent system inspired mainly by the one describe in [10]. That architecture has the advantage to be fully generic, and we think that it provides a good agentification for the analysis of morphology of massive multi-agent system. That system contains different kind of elements:

- Objects
- Sensor agent
- Agent
- Graph (as representation of morphology)

1. Objects

Object are the elements on which agents work. They contain information that agent read and products. This information depends on the ontology developed by the programmer. Objects are used to send information and get information between agents of the system and also between sensor of the robot and the system (throught the environment)

Several operations are available on the objects like aggregation, or composition between one and other objects. The composition is important to produced composed object and is highly related to the ontology chosen.

Another operation is the metric computation to allow comparison between two objects in order to evaluate the distance between them. Again the definition of this metric depends on the ontology used for the objects.

2. Sensor agent

They are special agents used as an interface between external environment's sensors and the internal multi-agent system. There main function is to produce objects from the data received from the sensors (regarding the ontology used). There are important because they spread objects in the environment that will change the behavior of the multi-agent system. The type of sensitivity for these agents can be whatever decides by the system's designer (position, average speed, acceleration, continuity of position value...).

3. Agent

Agents are the basic element of the multi-agent system, while the organization and their interactions have a structural role. The architecture [10] used in our work has been built in order to provide a generic behavior independent from the semantic of the problem and focus on the morphology of the multi-agent system. We briefly describe the main properties of the agent, for more details please refer to the original system describe in [10]

Each agent has a generic behavior with parameter that can be set individually. Each agent has also a particular role inside the multi-agent system. The role determines the context of activation of the agent and the objects that it will produce. For example if the agent's role is to detect a specific form, it will activated if it receive an object describing that form. Two agents activated with because of the same form may produce object slightly different regarding their own parameters.

The particularity of the system is that agent has a level of energy. This energy can be understood has the potential of an agent to be significant in the overall behavior of the multi-agent system. More energy has an agent, more the system take in account its behavior. However if the energy of the agent is null, the activity of the agent stop for a certain amount of time. This particularity is used to control the system's morphology as describe above.

4. Graph

The key of that system is the possibility to describe and compare morphologies of different phases of the system in order to correlate the sensor's activities and the multi-agent system.

In the system, the morphology is considerate here as the shape of agents activity from the aspectual organization The shape used to describe the aspectual organization's state are normalized and mean-centered histograms representing the agents distribution according to their production of objects.

Histograms have the advantage to make easily comparison between them, and offer few simple manipulations. For example the distance between to histograms will be the distances between the two vectors that they represent in the space of agent activities. It is also possible to classify histograms by considering the number of permutations needed from one histogram to another histogram. Also from technical point of view, this representation allows fast computation.

Example of application

1. AIBO robot

The system will be applied to AIBO robot. In this section, we shortly introduce the AIBO architecture.

AIBO is composed by several sensors and effectors. We have implemented our example using the four legs of AIBO. Each leg has three degrees of liberty called: Rotator, Elevator and Knee [fig. 2].

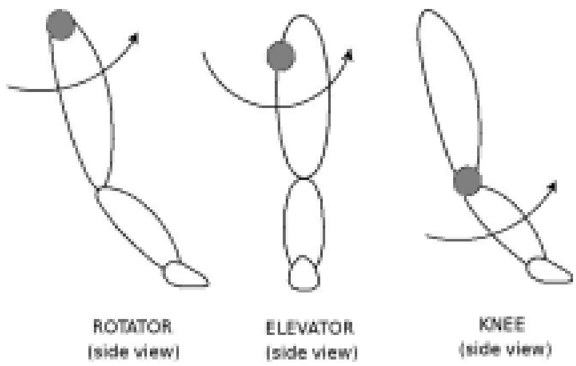


Figure 2: Description of the 3 degrees of liberty of AIBO leg.

The interface used for AIBO, is done with Tekkotsu [9]. This library allows us to get data of position of the legs at any time. We use this data as data from sensors for the position of each motor. We have set an interval of time to 10 milliseconds between sensors' data request. These data are read by a special type of agents, the sensor agent, as define below.

2. Objects

The objects produced by the agents are values representing the modification proposed in x or y of the value of the sensor on which he is linked. Each agent will propose to the effectors to modify by n degrees its current value. In our example, agents will make proposition for the new position of each leg.

3. Sensor agent

Sensor agent will produce objects in the environment from the data received from the sensors. Each of them is sensitive to one type of pattern produced by the sensor's data. They produce what we call a “pattern” objects. We associate a coefficient of correlation to the pattern that is recognized. We have chosen here to use neural network in order to select or recognize these patterns [fig. 3]

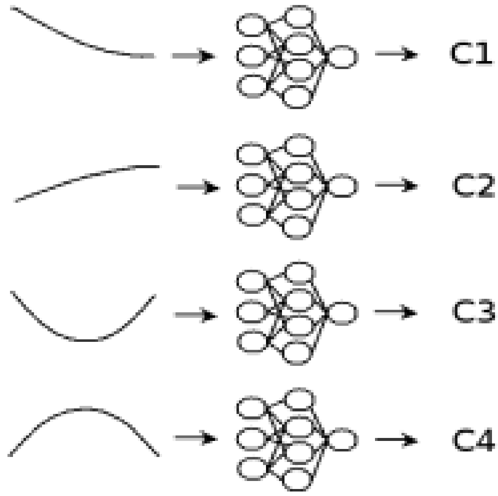


Figure 3: Example of types of pattern that are recognized
by the neural network associated to each sensor agent

Regarding the body architecture of AIBO, one agent sensor for one type of sensitivity will be connected to one of AIBO sensors.

4. Aspectual agent

Agent is sensitive to the object in the environment produced by the sensor agent. Each of the aspectual agents has of coefficient of activation. That coefficient set the level of correlation accepted by the agent in order to activate its role. Then if the correlation is above that coefficient of activation, regarding the object received, and if they are active (means they have some energy, then not temporally inactive), they produce an object containing the modification proposed in x and y, as describe previously. In our application, the coefficient of correlation is first randomly produced. We choose to associate fifty agents to each sensor agent. In theory, up to fifty agent can be activated for each sensor agent and produce an object, regarding the pattern object that they received.

At the next step, if the value proposed by the agent is nearly the one done by the effectors, the agent gets some energy. That will re-enforce temporally the action of the agent that make the right decision.

It is important to note that only the agents that have proposed a value near the one done by the effectors will be selected to be a part of the analyzed morphology (regarding the robot AIBO that means the histogram contains only agents that contribute to produce the movement).

Results

1. Learning morphology

First we were interested in testing what kind of morphology can be learned by the system regarding simple behavior of AIBO. We have let the system behave when AIBO is walking. [Fig.4] shows a basic output of data from the sensor when AIBO is walking.

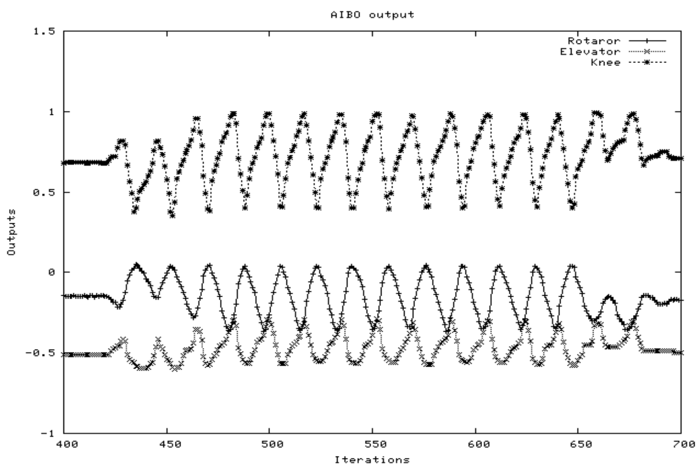


Figure 4: “Walking” output data

We focused our study to one step of walking, involving three effectors of one leg, to try to understand the behavior of the system, and what kind of morphology we can get. [Fig.5] shows one step from AIBO walking behavior.

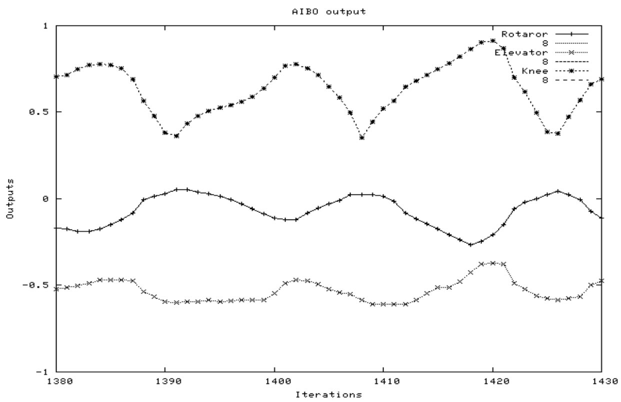


Figure 5: One step of walking behavior

From that output, we have saved morphologies that we got when the system is running. The next figure [fig. 6] presents the correlation results between two successive morphologies get at each iteration. The correlation is understood as the distance between the two vectors that represent the histogram of the morphology.

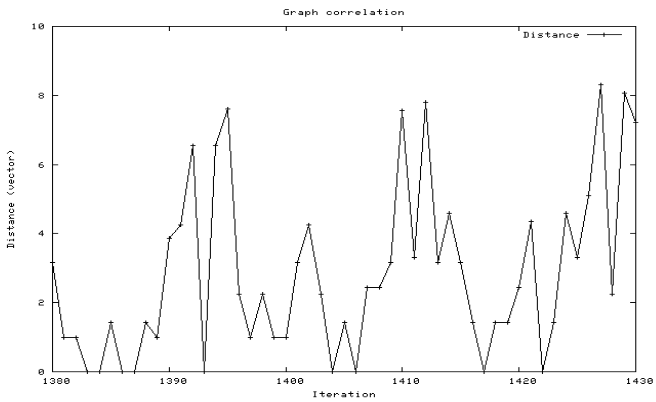


Figure 6: three types of morphologies that appear when the system is running.

That figure shows at three different points, a high distance between two successive histograms, respectively around the 1392nd, the 1395th and the 1402nd iteration (we can see the same three successive points at the next step around the 1420th, 1412th and 1421st iterations). These high distances reveal a succession of morphologies that change suddenly. That means in other terms that for one step, the system behave in three different ways, producing three kinds of morphology. The three type of morphology are represented in the histograms of [fig. 7, 8, 9]

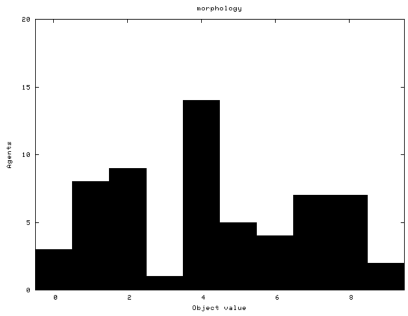


Figure 7: morphology from 1392nd and 1395th iteration

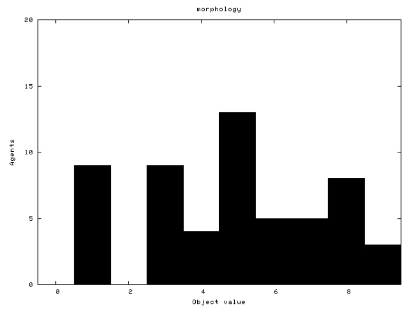


Figure 8: Multi-agent system morphology from 1395th and 1402nd iteration

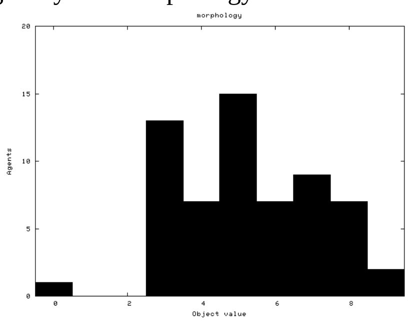


Figure 9: morphology from 1402nd and 1420th iteration

In that example we have connection between three morphologies that describe one behavior. This succession of those three morphologies will be considerate as defining a global morphology for the walking step behavior.

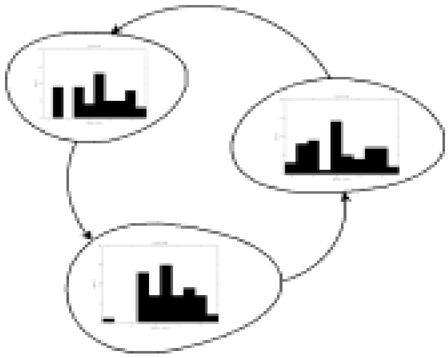
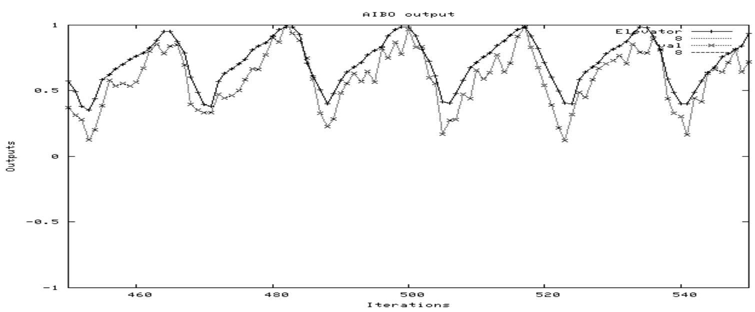


Figure 10: Succession of three morphologies gets from a walking step

In that part, we have proposed to investigate what kind of morphology the system can get on a simple example, the walking behavior. In the next part we will focus on the control of the system.

2. Control of AIBO using morphology

We were interested in that part to see how AIBO reacts when we try to force the system to reach one morphology describing a behavior (or succession of morphology). In this part we want to know the capacity of the system regarding a self-control.
The value of the sensor is the sum of the one proposed by the activated agent. These agents are activated by the analysis organization, that compare current morphology of the system and the one we want. To stimulate agent activities, we have given more energy to the agents that have been chosen, regarding their role and the one wanted to tend to the global morphology. That means that the agent will survive longer and its role will be more significant in the overall behavior for a period of time (this is the opposite from the learning phase, we reward the agent before he made the action…). Please note that at this part of our work, we have manually set the time for the succession (in term of iteration) of the three wanted morphologies (based on observation of [fig. 6]). The three figures show the result obtained until know for the "walking behavior" like control:



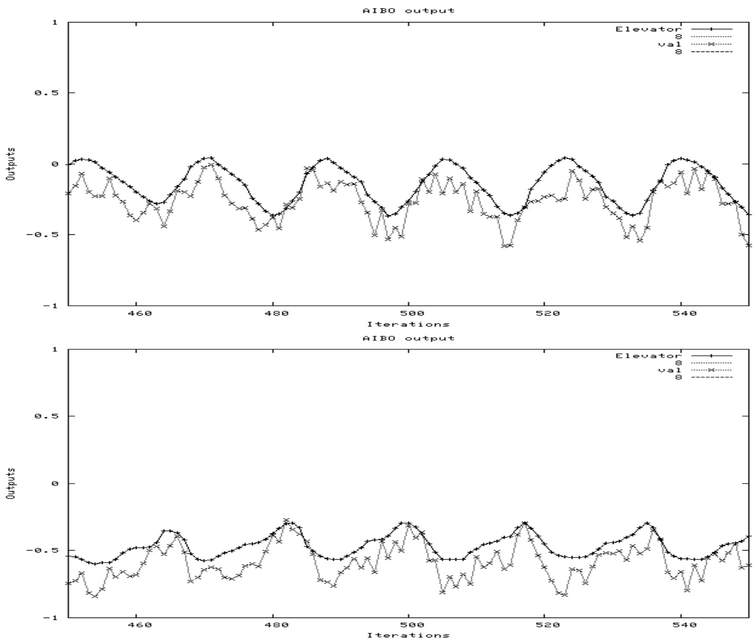


Figure 11: Values proposed by the system, compare to the original one, respectively for the knee, rotator and elevator of one leg of AIBO

In spite of the fact that the values present certain oscillations, we can see that these first results tend to show that the multi-agent system behave near what it is expected. One can notice that it may be hard to use such fluctuating values for a mechanical robot. It shows the necessity to focus a part of our work on getting more continuity for these values, to get more smooth behavior. But these results may show a possibility to develop a support for learning behavior and be able to partially re-use it in another context, like imitation for example.

Conclusion

We seek to develop a general method to analyze and control multi-agent system, and to make them self-adaptative. So far we have presented our current work based on internal state representation of a robot using part of that system. We proposed a method for connecting multi-agent systems to sensors and effectors in order to provide basic control and internal state representation of robot behavior. This internal state representation is based on notion of morphology. The morphology is described in our research as the shape representation of multi-agent organization in a geometrical way. A more deep understanding of properties of such description is necessary in order to make more fine correlation between AIBO behavior and the behavior of agents.

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