What your body and your living room tell my agent

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Abstract
This paper proposes a class of software agent architectures capable of playing some of beneficial roles embodiment accomplishes in living beings. These are component based architectures including sensors, actuators, emotion eliciting mechanisms and action control mechanisms. These architectures through their yellow pages and log services, which maintain updated information about the agent body and its dynamics, provide the means for the soft-visual appearance required for non-verbal communication and for learning through imitation. Component based architectures fulfil the requirement of efficient execution of agent functions in parallel and the possibility of using simplifying sensory-motor coordination. All components of architectures of the proposed class share the same goal of preserving the plans for the adaptive and situated construction of the agent. This feature plays the role of the body as an inner source of motives, enables the agent to have feelings and emotions, and allows the agent to centrifugally construct itself, avoiding non-grounding meta-control processes. Finally the proposed class of architectures integrate several learning mechanisms necessary for learning through imitation, for learning through direct manipulation of objects, for learning correlations among and computational complexity of the several aspects of the task and the environment, which allows the agent to replace slow with fast computations.

1. Introduction

Rich conversations involve much more than simple alternate turn-taking verbal messages exchange between the participants. Rich conversations involve non-verbal behaviours such as gaze, facial expressions, signals about willingness to take the turn, interrupt. Agents should smile, raise their brows, nods, and even gesticulate, not in a random manner but in co-occurrence with their speech [15]. All of these actions are synchronized to the actions of the other participant.

Embodiment provides the basis for this rich kind of communication. If each participant wouldn’t have a body the others could see and interpret, this rich non-verbal communication wouldn’t be possible. Embodiment, perception, and motor skills are thus critical in organizing action and communication.

This paper addresses the general problems of embodiment regarding both conversational agents and other kinds of agents in different types of settings. Moreover, the paper is concerned with the interaction among software agents rather then with the interaction between agents and people. The main contribution of the paper is to propose concrete architectural principles for software agents that enable them to benefit from the advantages embodiment accomplishes for living beings.

The paper starts with the analysis of the advantages of embodiment in living creatures, as identified by several authors, in particular regarding conversation (section 2). Section 3 presents the notion of soft-embodiment as the set of architectural features and mechanisms that play the roles of living organisms’ bodies in software agents. The section proceeds with the proposal of a class of architectures for soft-embodiment. This class of architectures enables software agents to take advantage of the identified benefits of embodiment. Section 4 presents conclusions and discuss future work.

2. Advantages of embodiment

The main issue in this section is not to determine whether or not it is possible to have disembodied intelligence. Rather, it discusses the possible benefits for intelligence and general behaviour that might be gained by having a body.

[6] can be interpreted as meaning that, due to its objective of preserving its genome, the body is an “internal” source of more specific motives.

People and possibly other high-level animals use none verbal communication through body expression, gestures, and postures, convey diverse types of information such as emotion, feelings and other mental states.

[7] reveals how to identify deceit in business, politics, marriage and public life by knowing what to look for in others’ faces, voices, bodies and words.

Learning through imitation is an important aspect of embodiment [13] since, although it is possible to imitate through the observation of the results of the action of other agents, it is not possible to imitate body expression if we don't see the imitated one. Therefore learning through imitation requires a body.

In order to be capable of learning through imitation, it is necessary to have perception (to see the imitated one or, at least, the result of his or her actions), it is important to have a motor system (to act the same way as the observed one), and it is important to have learning capabilities.

According to [10] the body provides the means for the child to learn through the direct manipulation of objects. The child learns concepts and schemas only when he or she learns to interact with objects in the world. Increasingly more abstract concepts are acquired through increasingly more complex interactions with the objects in the world.

Feelings and emotions provide the basis for important self-regulation homeostatic adaptive mechanisms both for the organism as a whole and for each of its parts. According to [4] and [5], feelings and emotions are essential for diverse cognitive activities such as decision making and social information processing. Emotions are processes in which the external environment and the internal state are evaluated against the motivation of the organism. If emotion eliciting conditions hold, an emotion-signal is generated warning the individual for relevant opportunities and threats, enabling it to react appropriately [1]. In agreement with [4] and [5], emotions are uncontrolled phenomena that take place outside the conscious awareness of the individual. Feelings take place when the individual becomes aware of the emotion. Whereas emotions take place in the public theatre of the body, feelings are private perceptions of the maps of the organism's body maintained by the brain. Therefore both emotions and feelings require the existence of the body.

Symbol grounding is the process by which the symbols manipulated by an agent acquire meaning to the agent itself by opposition of having meaning only to the external observer / agent designer. There are two classic approaches to *"grounding"*: cognitive grounding and enactive grounding.

By *"Cognitive Grounding"*, the agent first grounds the processed symbols (acquired or pre-programmed) in the results of perceptual processes and then builds meaning by the composition of more basic meanings. By *"Enactive Grounding"*, the meaning of the symbols is grounded not only in perceptual experience but also in action; perception is replaced by sensory-motor experience. *"Enactive grounding"* is done by the agent function.

Both approaches use a meta-control mechanism to learn the control mechanism. However, the meta-control mechanism is not grounded. In order to avoid a non-grounded mechanism that controls the way the acquired symbols are grounded, the agent function must be dynamically acquired by the agent through learning and self-organization. The agent should both learn its knowledge and its self-organization. Grounding requires co-evolution and mutual specification of the organism and the environment.

The symbol grounding problem is closely related with the possibility of higher-level cognition (i.e., deliberative symbolic processing) as opposed to the lower-level cognition (i.e., non-symbolic automatic processing) taking place outside our conscious awareness. By definition, higher-level cognition processes symbolic representations, which can have meaning for the agent itself only if they are grounded. Several authors propose that higher-level cognition can be grounded through embodiment [2][12][18] (but see also [3]).

[16] describes several experiments showing that control mechanisms are largely dependent on the type of used actuators. Control mechanisms and overall behaviour depend on the morphology and positioning of sensors. Required cognitive capabilities and intelligent behaviour depend on sensory-motor coordination and can be improved by changing morphology.

In physically embodied systems, sensory-motor coordination allows the system to select favourable sensory patterns that can be more easily processed than if no sensory-motor coordination had been used [14].

In general terms, intelligent behaviour depends not only on having a body carefully coupled with the environment but also on choices regarding materials (metal robotic arms require totally different control mechanisms than pneumatic arms), morphology (for instance, just by changing the position of its sensors, the same robotic entity exhibits totally different behaviours), sensory-motor coordination, and ecological balance (i.e., interdependence of task environment, morphology and neural processing).

Cognition complexity can be drastically reduced by careful embodiment. Sometimes, it is better to evolve sensors or motor control in order to keep cognition simple than the other way round.

[11] identifies several ways embodiment may reduce the complexity of the methods used in the agent's tasks, and organizes them into two types: those enabling the implementation of efficient algorithms, and those automatically selecting the best algorithms to use in each task.

Having a body enables the implementation of efficient algorithms, often analog, parallel algorithms. For instance, the shortest path between two nodes in a graph may easily be computed by constructing a graph of strings and knots, in which the strings are the graph arcs, and the knots are the graph nodes. If the knots representing the two nodes are picked up, it is enough to pull them away from each other until the strings linking them become tight. The length of the tight string is the shortest path between the nodes. This algorithm shows that, due to their important computational properties (e.g., computing their length in constant time) some kinds of bodies allow to implement efficient algorithms that could not be implemented as efficiently on a digital sequential computer.

Having a body enables automatically selecting the best algorithm to solve a given problem. [11] and [16] identify seven ways in which this type of simplifications may be achieved.

[16] provides examples showing that embodiment determines what kind of signals must be processed by the brain. Only those types of signals input by the sensors have to be processed by the brain.

High bandwidth coupling with the environment makes it possible to avoid hard abstract reasoning with models of the environment. For instance, just using vision, it is possible to walk across a room without hitting obstacles without building a mental model of the room. High bandwidth coupling with the environment allows important events to be *noticed* because information from the environment is continuously available and broadcast, they are not *checked for*; the cognitive system is triggered by interrupt mechanisms, not by poling.

Exploiting the structure of the task and the environment allows converting unrestricted abstract reasoning into simpler processes. For instance, travelling in a city from one point to another is much easier than path finding in a graph because there are signs, often the streets are parallel to each other, and some traffic restrictions reduce the number of possible routes.

Having a body can make viable approximate rather than exact solutions. For instance, a robotic arm can fit a key into a lock just by moving the key until it reaches the locker surface and then jiggling until it slips into the lock.

Through embodiment, the agent can reduce the number of degrees of freedom to be considered in its reasoning because physically embodied mechanisms have less degrees of freedom than generic software mechanisms. If the agent couples its actuators with the system to be controlled the number of degrees of freedom may be further decreased. For instance, tuning the radio by first putting our hand around it creating a coupled system is much easier than if the hand and the radio were decoupled. Once coupled, the resulting system has fewer degrees of freedom than if the arm and the radio were considered independently.

If some computationally hard aspect of the problem should be reasoned about and it is correlated with some other simple aspect, then the simpler aspect must be reasoned about instead.

Maintaining state information using the physical properties of the body and the environment (e.g., writing to-do lists, leaving a piece of paper in the freezer with a note, tying a rope to the finger in order to remember something) instead of using internal memory depends on high-bandwidth coupling with the environment as provided by embodiment.

3. Architectural principles for soft-embodiment

In this paper, the set of architectural features and mechanisms playing the role of embodiment for software agents is called soft-embodiment. This section presents soft-embodiment architectural principles covering soft visual appearance which is the requirement for non-verbal communication and for learning through imitation; the role of the body as a source of motives and the possibility to have feelings and emotions; the possibility of embodied systems of learning through direct manipulation of objects; the role of the body for symbol grounding; and the way the body enables the agent to efficiently accomplish its tasks.

3.1 Soft visual appearance

To some extent, component-based agent architectures can fulfil the requirements for non-verbal communication and for learning through imitation. These requirements include having the equivalent of visual appearance and perceiving the visual appearance of others, the possibility to make gestures, to exhibit body and facial expressions, and adopt body postures.

Each component making up the agent has its own set of roles / functions or is used to solve particular problems. The information regarding the agent’s components and their roles can be used by a second agent to create a static mental image of the parts integrating the first agent. This mental image can be interpreted as the static visual appearance of the first agent. The required information can be made publicly available to other agents if the agent component-based architecture provides a yellow pages service describing all the agent’s components together with their roles and conditions for their usability.

More important than the static image of an agent is its dynamics. In order to have non-verbal communication and learning through imitation an agent must know what the other agent is doing, what are its body expressions and its emotions in each moment in time.

If agent B can determine that one of the components of agent A has generated a positive surprise emotion-signal, B will be able to know that A is positively surprised. If B can know which of A's components was the responsible for the emotion-signal, B can infer more about the causes for the generated emotion signal.

If B can observe or determine that some other of A's components received the generated emotion-signal and changed its regular behaviour in response to the signal, B will be entitled to think that A has generated an emotion response.

Observing communication patterns between some of A's components may be enough to hypothesize for instance that A is receiving and maybe processing some type of external information.

Some other inter-component communication patterns may lead to the belief that the agent is selecting actions for execution.

There are some obvious differences between physical embodiment and soft embodiment with respect to non-verbal communication and to the possibility of learning through imitation.

In soft-embodiment, there are no such fine grained distinctions between body postures, body and facial expressions, and body gestures. Soft-embodiment provides other kinds of appearance, such as communication patterns, component working patterns, correlations between these patterns.

Soft-embodiment appearance does not require high-bandwidth communication to be perceived by the observer because the amount of information describing soft-embodiment is much less than the amount of information in a visual image. Besides, soft-embodiment visual appearance may involve more hypothetical reasoning by the observer than reasoning about physical visual images.

In order for the dynamic component of the agent soft-visual appearance be publicly available for inspection by other agents, the component-based platform must provide a log service maintaining a record of the agent's workings. It is necessary that, each time a component receives a task to be handled, it informs the platform log-service that it has received a request from the requesting component to handle the task and started handling it. When the component finishes handling the specified task, it must also inform the log-service that the task has been finished together with its completion state (successful vs. error conditions).

If emotion-signals, information and commands are generated by some of the agent's components and sent to other components, the generating component must inform the platform log-service.

Finally, if the normal operation of a component is interrupted, suspended, and some non-planned task starts being performed, the component must also inform the platform log-service.

The platform log-service must have an internal information management service in order to remove information that is not used anymore so that the amount of maintained information does not reach intractable size.

The agent's log service provides the necessary dynamic information regarding the movement of the agent soft-visual appearance.

Soft-visual appearance is not enough for non-verbal communication and for learning through imitation. Agents must have sensors that receive information from other agent's yellow pages service and log-service. Agents must also have learning capabilities allowing them to learn and to build models of other agents from the received information.

Component-based architectures also fulfil other requirements of embodiment as will be seen in next sections.

3.2 Source of motives, possibility to have feelings

The body of a natural organism is an inner source of motives (e.g., goals, desires) due to its ultimate biological objective of preserving its genes. In order to create a software agent architecture that plays the role of being an inner source of motives, it is necessary to endow it with the equivalent of such biological objectives.

Natural living organisms are engineered by their genome as survival machines aimed at the preservation of their genes. The genes play the role of the plan for the construction of the organism, that is, of the survival machine that will strive to preserve them.

Is it necessary that the ultimate objective of the software agent is to propagate the plans for its construction through procreation to its offspring? Or is it enough to have some objective implicitly or explicitly created by the agent designer? If being an inner source of motivation were the only role played by the body then any objective would be as good as any other. However a proper answer to this question implies that some other roles of soft-embodiment be analysed.

According to [5], human feelings are the perception of the body maps created and continuously updated by the individual brain[1]. Fortunately, in order to fulfil the requirement for visual appearance, the agent must have a yellow pages service and a log service that maintain and update all relevant information about the agent's body. This information can be considered the map of the agent's body necessary to have feelings.

However, in order to have feelings, it is not enough to build and maintain an updated map of the organism body. It is necessary that the organism depends on the good functioning of all its parts, and that the monitored parts of the organism have their own goals whose satisfaction depends on the functioning of the whole organism. That is, it is necessary that the good functioning of the whole and the good functioning of each of its parts is relevant for the part itself. Events and states of affairs become relevant for some entity only if the entity has an objective whose satisfaction is facilitated or impaired by the event or state of affairs. The body map built and maintained by the individual brain reflects the interpretation of the current state of affairs as provided by each of the organism's parts with respect to its own objectives. Perceptions of these maps – feelings – are used by the whole and by each of the organism's parts for regulation purposes. Feelings are so important because they enable a self-regulation, homeostatic mechanism both for the organism as a whole and for each of its parts.

Given the importance of feelings and given that feelings are possible only if each monitored part of the organism has its own goals, the proposed software agent architecture will be made up of components each one with its own goals.

All the cells in living organisms have the same ultimate objective – the preservation of their genes. By analogy, all the software agent's components share the same objective in the proposed class of architectures.

As previously discussed, one of the roles of the body of a living organism is to be an inner source of motivation (e.g., goals). This is achieved in a software agent if the agent is built with its own goals. Since, in order to have feelings all parts of the software agent must have their goals, it is natural that the goals necessary for the agent to have feelings may also work as an inner source of motivation for the agent. This means that the same architectural principle satisfies two of the identified roles played by embodiment – having feelings and the associated regulation mechanisms, and being an inner source of goals and other motives.

3.3 Learning through objects manipulation

For physically embodied systems, learning through the direct manipulation of objects in the world requires the capacity to manipulate physical objects. However, for software agents in software worlds (such as virtual environments and the Internet), most often the agent just manipulates software objects. This means the manipulated software objects must have some intrinsic behaviour that can be mastered through its repeated manipulation in a trial and error process in which the agent receives feed back of its manipulations. Sometimes though, software agents control physical systems (e.g., production process control systems, autonomous vehicle control systems, and intensive care units control systems). When the software agent controls physical systems, the kind of learning through direct manipulation that takes place in child development may also be used, if there is some feedback from the physical control system to the software agent.

3.4 Symbol grounding

In the proposed class of software agent architectures, symbols will be grounded in several ways depending on their nature.

Symbols acquired through social interaction will be grounded in social interaction activities. Symbols acquired through sensory activities will be grounded in the sensorial activities originating them. These symbols will be associated with other symbols of the same nature using associative memory, so that recollection of one symbol facilitates recollection of associated symbols in the same context, contributing to mutual grounding. Symbols representing abstractions of learnt sensory-motor activities will be grounded in those activities. Grounding of symbols in low-level sensory-motor activities require an agent architecture in

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[1] The phenomenal experience associated with feelings is due to the conscious awareness of the feeling and their symbolic meaning (positive feelings mean the organism and its parts are in a positive state of affairs and the converse for negative feelings). Feeling expressions and the conscious awareness of feelings are acquired during the social interaction of the organism, for instance through imitation.

which routine behaviour can be learnt through the unmediated *comportment* of the agent with the environment [9][17].

Symbols reflecting internal ideas and feelings will be grounded in the maps of the body built, maintained and updated by the agent [5] in the platform yellow pages and log services (see section 3.1).

More abstract symbols will be grounded in less abstract symbolic structures. This requires that higher level cognition operates upon multiple-levels of representations, each of which is grounded in the level immediately beneath it.

The possibility to have immediate access to the meaning of a symbol depends on the way the symbol was grounded. For instance, immediate access to the meaning of a symbol grounded in motor activities involves internal simulated replay of those activities. Access to the meaning of symbols acquired through social interaction or via pure sensorial activities involves retrieval of associated information from memory and internal simulated replay of the activities in which the symbol has been grounded. Access to ideas and feelings about the self involves retrieval of relevant fragments of the maps of the body in which they have been grounded.

In any case, acquired symbolic representations must be tagged with all sorts of episodic information regarding the context in which the symbol was acquired, including emotional information.

Unfortunately, the described grounding process involves a meta-control process that is not itself grounded. In order to avoid the existence of a non-grounded meta-control processes, [18] proposes the co-evolution and mutual specification of the organism and the environment. This is the goal of organismic embodiment, which involves the centrifugally creation of the organism's components occurring in autopoietic organisms. Therefore, the agent architecture must use evolutionary processes through which the agent self-organizes, creates its own parts, learns its behavioural rules in co-evolution with the environment.

The above requirement is closely related with the problem of defining the ultimate objectives that must be possessed by each component of the agent soft body. In fact, in order to be possible for the agent to centrifugally develop itself, it is necessary to have the plans of its adaptive construction. That's exactly the role of the organisms' genome – plans for the adaptive, situated construction of the organism. Therefore, the ultimate and shared objective of each of the agent's components is the preservation of the plans for its adaptive, situated construction. These plans will allow agents to centrifugally create themselves, the same way a single cell (resulting of sexual reproduction) develops a full organism.

3.5 Enabling efficient accomplishment of agent's tasks

The efficient accomplishment of agent's tasks enabled by embodiment stem from the parallel execution of agent functions, the capability of replacing slow with fast computations, the possibility of reducing the information to be processed, and a high-bandwidth coupling with the environment. This subsection discusses each of the above requirements in the software agents' context. The ability of reducing the number of degrees of freedom of the system to be controlled will be left for future work.

It has been recognized that one of the advantages of embodiment is that often the body allows parallel execution of algorithms which results in more efficient processes. The component-based architectures proposed in this paper also allow parallel execution since they are distributed architectures. The agent function is distributed by several components each of which may run on a separate computer. This means the component based proposal accomplishes several requirements of embodiment: soft-visual appearance, possibility to have feelings and the efficient execution of parallel algorithms. This requirement is accomplished in architectures in which the agent functions are designed so that they can run in parallel.

In order to allow the replacing of slow with fast but equivalent computations, the agent must learn the correlations among the aspects that need to be processed. It must also learn a model of the computational complexity of processing each aspect of the world or of the task. Knowing the correlations among the several aspects of the task and the environment and their computational complexity, the agent may decide to replace complex computations of some particular aspect by simpler computations of a correlated aspect.

Efficiency can also be gained if the agent is capable of reducing the amount of information that needs to be processed. Careful agent design can shape the agent's information processing mechanisms for the types of inputs provided by the agent sensors. However if the type and number of sensors change in run-time, then the agent must adapt its information processing mechanisms to the types of inputs provided by the new set of sensors. The architectural principle is a middle layer designed as an evolutionary algorithm that learns to adapt information processes to the currently existing sensors and its inputs.

Attention mechanisms, effective filtering techniques such as foveation in the retina (i.e., most of the information is thrown away), and reacting differently to different sensory patterns can also reduce the information that needs to be processed. This can be achieved through sensory-motor coordination.

[14] shows how sensory-motor coordination can simplify the task that has to be preformed by the agent. If software agents are to benefit from the advantages of being embodied, their architectures must explore sensory-motor coordination.

Besides reducing the amount of information that needs to be processed, sensory-motor coordination may also reduce task complexity.

In virtual environments (e.g., in games), the sensory-motor coordination can be achieved by the same processes used in the physical world.

In real soft-worlds such as information worlds, sensory-motor coordination can also be used to reduce the amount of information that needs to be processed and to reduce the complexity of information processing. For instance, an information retrieval agent searching the internet for some desired information may use different sites in its search. Without sensory-motor coordination, the agent's sensors will provide all information extracted from the several visited sites. In this kind of scenario, sensory-motor coordination means for instance to use one site as the main source of information and use other sites only to complete information not present in the main site. Another example of sensory-motor coordination is to use the Google[2] or the Metacrawler[3] search engines which integrate information from several sources, instead of explicitly visiting all information sources.

Information agents and other software agents operating in real soft-worlds may built alternative views of the information they extract from the world. Sensory-motor coordination may also mean to select the most adequate view to be processed or to perform some kind of integration before the agent' sensors send it to be processed.

If the retrieved information consists of textual descriptions and images, sensory-motor coordination may also mean to build an information view in which each image is integrated with the corresponding description forming an object that will be easier to process by the agent.

In all the above situations sensory-motor coordination involves coordinating the agent's actuators (e.g., the sites it visits, and the order by which they are visited) so that the sensors can create appropriate views of the world. Appropriate views are those that contain less information to be processed (without loosing relevant information) or those views containing information that is more easily processed than the other views. Although some view may contain relevant information at the eyes of the observer, sometimes it can be reduced if the agent is not capable of handling all of it.

The architectural principle necessary for sensory-motor simplifications is thus a middle layer controlling sensors and actuators so that sensors can select the most appropriate world vision to be sent for processing.

High-bandwidth coupling with the environment, as provided by the kind of sensors of biological bodies, allows the agent to use more effective and efficient methods to accomplish its tasks. The gains of efficiency allowed by high-bandwidth coupling with the environment stem from the possibility to replace mental models of the environment with perception, the possibility to transfer state information from the agent to relevant properties of the environment, the capability to automatically noticing relevant events without the need to explicitly checking all possibilities that may arise, and the possibility of reducing control requirements.

In some soft-environments such as virtual worlds, digital libraries, auctions, and the Internet it is often possible to have a good coupling with the environment without requiring high bandwidth. All the information in a virtual world can be made available to the software agent by designing the agent and the environment as a whole. This kind of design allows the agent to have access to all information regarding the environment without using vision and other sensors. It is also possible, in these cases, to design the noticing mechanism using interrupt-based programming (also termed programming by events).

The amount of information and the rate of information change in several soft-environments such as the Internet, electronic auctions, digital libraries and other Internet based environments do not require the same kind of high-bandwidth coupling with the environment as required in physical environments.

Finally, the capability of observing other software agents so that non-verbal communication and learning through imitation can take place does also not need high bandwidth sensors since soft-visual appearance involves much less information than physical images.

4. Conclusions and Future Work

This paper presents some advantages of embodiment in living beings as identified by several researchers in the areas of philosophy, psychology, neurology and engineering, and proposes a set of principles defining a

[2] http://www.google.com
[3] http://www.metacrawler.com/

class of software agent architectures that can play some of the same beneficial roles embodiment plays in living beings.

The ability to reduce the degrees of freedom of the system to be controlled was not addressed in the current version of the proposed set of architectural principles for soft-embodiment. This will be the first direction of future work.

The architectural principles and mechanisms outlined in section 3 define a class of software agent architectures capable of playing some of the beneficial roles of embodiment. However they have not been implemented in a concrete architecture. A future direction of work will be to use the Salt & Pepper component-based architecture (*XSPLatform*, eXtended Service Platform) [8] as the basis for a specific agent architecture compliant with the defined principles.

Components too must have general properties they do not have in the current version of the platform. Components must be capable of informing the platform log-service that they have initiated handling a request from another component. They must know what their normal operation is and when it is interrupted and suspended by some non-planned task. They must know when they have completed the execution of each task and the corresponding completion state. They must also know the identity of the components that have requested them to perform a task and the identities of the components to which they have sent emotion-signals, information or commands.

Other forms of symbol grounding such as grounding in cultural memes as proposed by Bryson [3] will also be investigated.

Another direction for future work is the development of a pictoric representation of the agent's soft-visual appearance that can be displayed in the computer screen and evaluated by people. This will allow us to have a clearer idea about the requirements on soft-visual appearance for non-verbal communication and learning through imitation. This will also allow us to figure out the appropriate level of detail that is required regarding the agent's soft-visual appearance and compare it with the visual appearance of physically embodied creatures.

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