Empowering Agents within Virtual Environments

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Abstract - *An agent's embodiment within a virtual environment refers to its representation, and defines its capabilities, within the environment. This paper presents a system for the strong integration of embodiment with the agent's deliberative mechanism. This mechanism is based upon the Belief-Desire-Intention (BDI) paradigm, and allows the agent to deliberate directly upon the location and animation of its embodiment. This fusion then provides the agent with the ability to freely mutate its embodied form to best suit the task at hand. At the same time, care must be taken to preserve the agents' sense of self, so that users have a clear idea of who their agent is regardless of the embodiment that it has adopted. This paper outlines the system designed and developed to achieve this. This work forms part of the Agent Chameleons project, which aims to create agents that are free to migrate, mutate and evolve within and between various different environments and platforms.*

Keywords: Agent Chameleons, Embodiments, BDI, Identity.

1 Introduction

Over the last number of years, extensive research has been carried out into the area of autonomous agents. The term *agent* can be somewhat nebulous and invoke different meanings depending on the discipline in question. We use the term in a manner synonymous with the Distributed Artificial Intelligence (DAI) community, that is, agents are characterised by the attributes of autonomy, social ability, reactivity and pro-activity [12]. Furthermore, a stronger notion of agenthood also assigns mentalistic attitudes, that is, knowledge, belief, intention and obligation.

In parallel, significant developments in Collaborative Virtual Environments have occurred of late. A number of different systems have sought to incorporate agents within virtual environments. Notably, these include the MAVE system developed by Cobel, Harbison & Cook [4] [3], and the VITAL system developed by Anastassakis et al. [1]. Some important research has also been carried out by Torres et al. [11], and by Huang et al. [7] in integrating BDI based agents within virtual worlds.

Further to this, much research has also been conducted which examines embodiment. *Embodiment* refers to provision of an appropriate representation for an agent or a user within a virtual environment, for the benefit of other agents and users, as well as for the agent itself [2]. It should be noted that the agent's choice of embodiment form dictates the agent's interaction with its environment, as the agent abilities to sense and to affect the world are limited by its body.

This research aims to achieve a fusion of the notion of embodiment with that of the agent itself, so that the two become inextricably linked. The embodiment is no longer a shallow container as its behaviour is governed by an intelligent process. Such empowered entities ought to be devoid of constrains and capable of adapting to suit the task at hand. This fusion of the embodied form with the deductive apparatus that governs the behaviour of that form, we term as the *agent chameleon*.

2 Agent Chameleons

The Agent Chameleons project [6] [8] [9] [10] endeavours to create the next generation of virtual agents, autonomic entities that can seamlessly migrate, mutate and evolve between and within real and virtual information spaces. The Agent Chameleon can be seen as a digital *spirit*, capable of occupying and controlling a physical entity such as robot, or an embodied container, like an avatar. This is shown in figure 1.

The ultimate survival and longevity of agents is predicated by their ability to sense, react and respond to environmental change. The response can take the form of migration across a wireless network, mutation of the agent's embodiment, or evolution of the agent's form and associated capabilities.

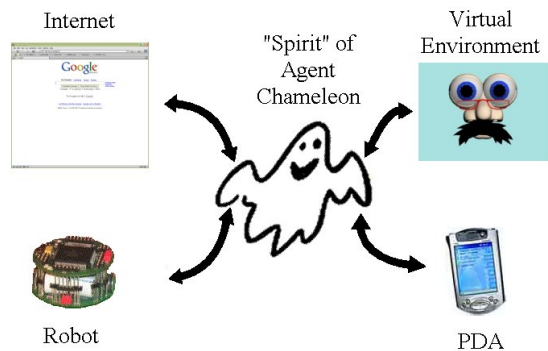The key to this system is the method whereby

Figure 1. The agent can be seen as a digital spirit, capable of occupying various different bodies.

the agents can migrate between the various information spaces. Agents should be capable of migrating on to a wide variety of devices in order to utilise the features of each. For instance an agent could migrate to a real world robot in order to achieve a physical manifestation and influence physical reality, to a PDA in order to travel with the user, or to a virtual environment in order to improve its abilities to interact with the user. The architecture of the system that achieves this is outlined in [6].

The environment and embodiment of the agent defines the capabilities of the agent, and hence its behaviour. Agents should be capable of deliberatively selecting their embodiment and platform in order to help them achieve their goals. This paper examines the provision of agents with the ability to mutate their embodiment form within virtual environments, and some of the needs and implications of this.

The Agent Chameleons may have several applications, for instance as a virtual assistant, following the user between various different spaces and capable of employing the advantages of each. For such an agent, the environments that might be required include the user's desktop and laptop computers, where it can be assume a 3D virtual embodiment, their PDA or mobile phone, where it may require a simpler 2D embodiment, or some group virtual environment, where the agent may go to in order to interact with other agents.

3   Mutation

Key to maintaining the presence of the agent chameleon within the virtual world is the agent's embodiment, or the nature of the avatar representing the agent. Virtual agents have traditionally been confined to a single form of avatar, a single embodiment. This

research proposes a different approach, our vision is of a system whereby an agent can mutate its form between various different embodiments in order to suit the task at hand.

This provides the agent with a number of advantages. Without the constraints on the embodiment, the agent chameleon is now capable of selecting the embodiment most suitable to its needs. For example, in a space environment the agent could adopt the form of a rocket, allowing it greater freedom of movement. If it requires verbal interaction with the user, the agent could adopt the form of a face, limiting its movement but providing it with the ability to express certain facial expressions.

This freedom provides agents with enhanced flexibility, allowing for an expanded set of uses within the virtual world. It is vital that these embodiment changes are under the control of the agent's deliberative mechanism. In addition, the position of the agent within the virtual world and its animation must also be controlled by the deliberative mechanism of the agent. The agents must have full knowledge of the possible animations that the embodiment is capable of and be possible to execute these.

The agent is capable of forming, and executing, plans that incorporate changes in embodiment, animation and motion. In this way the embodiment of the agent and its deliberative mechanism are fused in order to form a single notion.

4   Identity

The opportunity for an agent to autonomously change its embodiment freely and easily presents a number of identity problems. If the agents can change its form, how can the notion of the agent be maintained in the mind of the user? This is an essential requirement if the user is to empathise with the agent, and to develop a relationship with it. The sense of identity of the agent must be preserved, across all of the possible embodiments that it can adopt, with common visual cues or themes that are identifiable in all embodiment forms.

Designers of the embodiments must take care to maintain the agents sense of self, ensuring that certain factors remain constant across all embodiments. Common colour schemes or particular face markings could be used in order to do this. Non visual factors such as the tone of voice of the agent could also be used. This sense of identity applies not only to virtual environments, but to other platforms that the agents can occupy. Other platforms such as robots or PDA's could attempt to use the same common features.

An example of a series of agent embodiments that illustrates is given in figure 2. As can be seen, the use
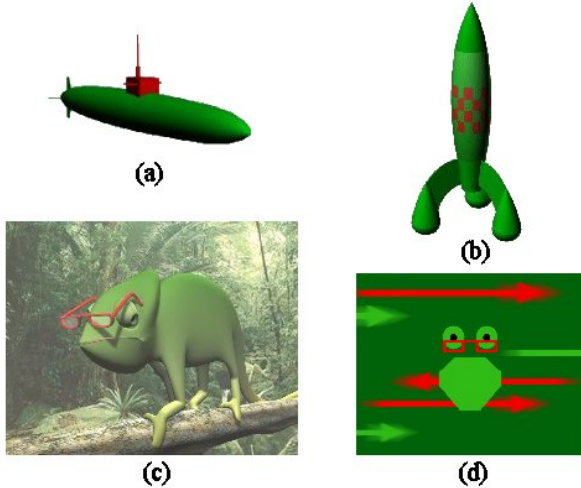
Figure 2. Some of the embodiments that an agent can adopt, including (a) A submarine, (b) a rocket, (c) a chameleon suitable for a forest style virtual world and (d) and a simpler embodiment suitable for a PDA or mobile phone. Note that the green and red colour scheme, and the glasses, are preserved in order to maintain the agents sense of identity.
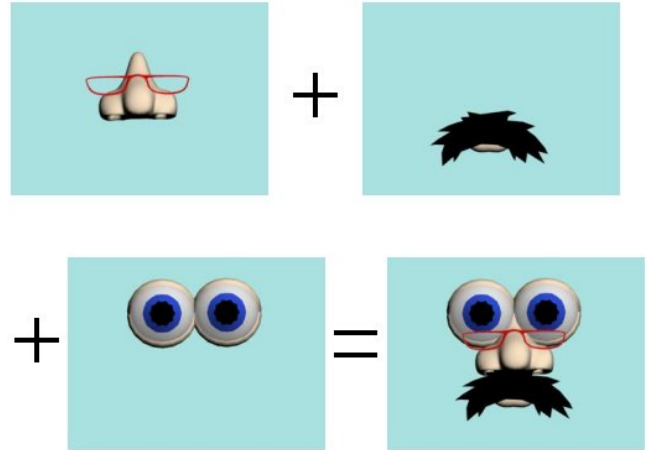

Figure 3. Each embodiment is made up of a number of embodiment elements, each of which can be animated independently. For example this embodiment consists of three elements, the eyes, the nose and the moustache and mouth.

of a red and green colour scheme provides the agent with an identity within the mind of the user, despite the obvious physical differences, further aided by the use of glasses.

5 Architecture

In order to achieve these requirements we propose an architecture for agent chameleons within virtual environments. Within this architecture an embodiment can be seen as a collection of *embodiment elements*, as illustrated by the example in figure 3. Each element corresponds to a definite piece of geometry in the avatar. The animations of each element can be defined, these operate based upon a series of animation states. Each element consists of a number of states that define particular key frames at which the animations overlap. These are points where the geometry is in a common position, synchronisation points at which the animations can be stitched together. These are linked to other states by the animations that the element can undergo, forming a directed graph of possible animations. The agent can then traverse this graph of each of its embodiment's elements, executing the required animations as it does. This is shown in figure 4.

The agents' deliberative mechanism is based upon Agent Factory [5]. Agent Factory provides a cohesive framework for the development and deployment of agent-oriented applications. Specifically, it delivers extensive support for the creation of Belief-Desire-Intention (BDI) agents. The Agent Factory Run-Time Environment delivers support for the deployment of agent-oriented application across a large number of platforms.

Reasoning within agent factory is based upon a series of beliefs. A *belief* is a statement of what the agent believes to be true at the current moment. I should be noted that this beliefs need not necessarily be true, but the agent believes them to be true and reasons accordingly. The behaviour of the agent is defined by its *commitment rules*. These define under which set of beliefs the agent will adopt a particular commitment. Commitments represent pledges to assume a course of action. They represent the outcome of the agents decision-making process.

The agent is capable of reasoning about the embodiments. It has beliefs about its current embodiment and other possible embodiments that it can adopt, and it can commit to switching between embodiments at will. It also has beliefs regarding the animation state of the elements of its embodiment and the avatars position within the virtual world, and can commit to changing the animations and moving about within the world.

6 Conclusion

Virtual Agents are more flexible when they are unconstrained by their embodied forms. We envision agents, free to mutate their embodiments in order to take full advantage of them. However, throughout these embodiments, it is important that the agents maintain
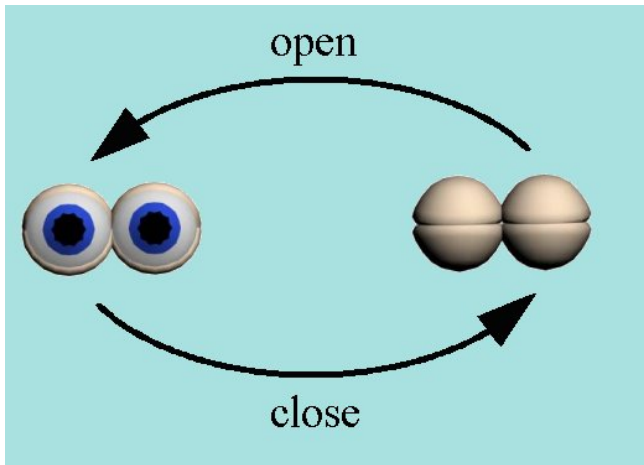
Figure 4. Animations are controlled through the use of an animation graph, that defines the possible animations for an embodiment element. In this case the eye element allows opening and closing.

a sense of identity.

The Agent Chameleons Architecture for Virtual Environments can help to achieve this. The architecture allows agent full control over their embodiments, allowing them to mutate their forms at will. These changes are fully controlled by the agents deliberative mechanism, and hence the agents and embodiments become fused to form a single agent chameleon. The architecture also allows the agent designer to easily and effectively create and modify the possible embodiments of the agent.

This architecture form part of the Agent Chameleons Projects, which aims to create agents capable of migrating between, and using the capabilities of, various different platforms and environments.

References

[1] George Anastassakis, Tim Ritchings, and Themis Panayiotopoulos. Multi-agent systems as intelligent virtual environments. In *Advances in Artificial Intelligence, Joint German/Austrian Conference on AI - KI 2001*, volume 2174 of *Lecture Notes in Computer Science*. Springer, September 2001.

[2] Steve Benford, John Bowers, Lennart E. Fahlén, Chris Greenhalgh, and Dave Snowdon. User embodiment in collaborative virtual environments. In *Proceedings of CHI 1995*, 1995.

[3] Jeffrey Cobel and Diane J. Cook. Virtual environments: An agent-based approach. In *Proceedings of The AAAI Spring Symposium on Agents with Adjustable Autonomy*, 1999.

[4] Jeffrey Cobel and Karen Harbison. MAVE: A multi-agent architecture for virtual environments. In *Proceedings of the 11th International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems*, pages 577–583.

[5] Rem Collier, Gregory M. P. O'Hare, Terry Lowen, and Colm Rooney. Beyond prototyping in the factory of agents. In *Proceedings of The Third Central and Eastern European Conference on Multi-Agent Systems - CEEMAS'03*, Prague, Czech Republic, 2003.

[6] Brian R. Duffy, Gregory M. P. O'Hare, Alan N. Martin, John F. Bradley, and Bianca Schön. Agent chameleons: Agent minds and bodies. In *Procedings of Computer Animation and Social Agents - CASA 2003*, May 2003.

[7] Zhisheng Huang, Anton Eliëns, and Cees Vissser. Programmibility of intelligent agent avatars. In *Proceedings of Agent'01 Workshop on Embodied Agents*, Montreal, Canada, June 2001.

[8] Gregory M. P. O'Hare and Brian R. Duffy. Agent chameleons: Migration and mutation within and between real and virtual spaces. In *Proceedings of The Society for the Study of Artificial Intelligence and the Simulation of Behaviour (SSAISB) - AISB'02 Conference*, April 2002.

[9] Gregory M. P. O'Hare, Brian R. Duffy, John F. Bradley, and Alan N. Martin. Agent chameleons: Moving minds from robots to digital information spaces. In *Procedings of Autonomous Minirobots for Research and Edutainment - AMiRE 2003*, February 2003.

[10] Gregory M. P. O'Hare, Brian R. Duffy, Bianca Schön, Alan Martin, and John F. Bradley. Agent chameleons: Virtual agents real intelligence. In *Proceedings of The Fourth International Working Conference on Intelligent Virtual Agents - IVA 2003*, volume 2792 of *Lecture Notes in Computer Science*, pages 218–225, Irsee, Germany, September 2003.

[11] Jorge A. Torres, Luciana P. Nedel, and Rafael H. Bordini. Using the BDI architecture to produce autonomous characters in virtual worlds. In *Proceedings of The Fourth International Working Conference on Intelligent Virtual Agents - IVA 2003*, volume 2792 of *Lecture Notes in Computer Science*, pages 197–201, Irsee, Germany, September 2003.

[12] Michael Wooldridge and Nicholas R. Jennings. Intelligent agents: Theory and practice. *Knowledge Engineering Review*, 10(2), 1994.