

Maintaining the Identity of Dynamically Embodied Agents

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Abstract. Virtual agents are traditionally constrained in their embodiment, as they are restricted to one form of body. We propose allowing them to change their embodiment in order to expand their capabilities. This presents users with a number of difficulties in maintaining the identity of the agents, but these can be overcome by using identity cues, certain features that remain constant across embodiment forms. This paper outlines an experiment that examines these identity cues, and shows that they can be used to help address this identity problem.

1 Introduction

Over the last number of years, extensive research has been carried out into the area of autonomous agents. These are software entities characterised by the attributes of autonomy, social ability, reactivity and pro-activity [1]. A number of features of agent technologies, including their autonomy, their ability to reason based upon limited knowledge and their ability to react to changes in the environment, make them suitable for use within virtual environments. Agents within virtual environments are referred to as *virtual agents*. We propose a system in which virtual agents are controlled by a *Belief-Desire-Intention* (BDI) architecture [2–4].

A number of different systems have sought to incorporate agents within virtual environments. These include the MAVE system developed by Cobel, Harbison & Cook [5, 6], which seeks to place virtual agents within a web based VRML environment. In contrast to our use of BDI, the deliberation of these agents is based upon Bayesian reasoning. André and Rist have developed MIAU, a system that animates characters based upon either a behaviour component or a response to user interaction [7].

A number of other virtual agent systems exist that embrace BDI based reasoning, as we do. These include the VITAL system developed by Anastassakis et al. [8], systems developed by Torres et al. [9] and Huang et al. [10], the Avatar

Arena system developed by Rist et al. [11] and PsychSim, a system for the control of synthetic characters used to educate children in how to recognise and deal with bullying [12].

Traditionally an avatar is constrained to a single form, including in all of the above systems. This has a number of limitations on the avatar’s capabilities, as the capabilities are defined by the form of the avatar. We advocate a different system, the agent is capable of mutating its embodiment in order to expand upon its capabilities. The embodiment is dynamic and can change in order to take advantage of different capability sets. However, this freedom does present a number of difficulties, particularly in relation to the agent’s identity.

Maintenance of identity, despite the ability to change form, is vital. In order to achieve this, we propose a system whereby agents are equipped with a number of *identity cues*. These are distinctive features that are common to all of the possible forms of the agent. In this paper we examine the influence of these cues in maintaining the agent’s identity.

Sect. 2 introduces Agent Chameleons, a system for the provision of expanded capabilities through migration, mutation and evolution. Sect. 3 discusses embodiment and suggests how the embodiment could be capable of change. Sect. 4 looks at identity and how it can be maintained with dynamic embodiment. Sect. 5 then explains the experimental methodology used to examine this notion, with the results detailed in Sect. 6.

2 Agent Chameleons

This research forms part of the the Agent Chameleons project [13–15], in which we endeavour to create the next generation of virtual agents, autonomic entities that can seamlessly migrate, mutate and evolve between and within virtual information spaces. The Agent Chameleon can be seen as a digital *spirit*, capable of occupying a variety of different platforms, such as a physical entity (a robot), a virtual environment, or a mobile device such as a PDA.

The key concepts of migration and mutation underpin these agents, allowing them to react to environmental change. Agent Chameleons are capable of migrating to a wide variety of devices and information spaces as required, in order to utilise the features and capabilities 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 for interacting with the user.

Additionally, the agents are capable of mutating their form. This is particularly relevant within virtual environments, where the form of an agent is not constrained, as it is in the real world, and is capable of changing to suit the task at hand.

Within Agent Chameleons, the agents’ deliberative mechanism is based upon Agent Factory [16–19]. 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 applications across a large number of platforms. The system has been created to provide these agents with control of a number of platforms and devices, and providing them with the ability to migrate between them. [14, 15, 20, 21]

3 Embodiment

The relationship between mind and body has been a psychological and philosophical problem for many years. For example, Descartes [22] argued that the mind and the body are distinct entities and can interact independently of one another. Within the Artificial Intelligence (AI) community, this question has also arisen. Popularised by Brooks [23], the predominant position is that while the mind and body can be seen as separate components, they are not necessarily inseparable. The embodiment of the intelligent system is crucial, as it is through this embodiment that a system interacts with the world.

Within virtual environments an agent's (or a user's) embodiment has been defined as the provision of an appropriate body image for the representation of that agent to other agents and users, as well as to itself [24]. Normally, a virtual agent is embodied through an *avatar*, a graphical representation of the agent within the virtual environment. The use of embodiment within a virtual environment is crucial for the user to develop a sense of presence within the world. *Presence* refers to the subjective experience of being in one place or environment, even when one is physically situated in another [25]. Gerhard et al. state that the use of avatars to embody users within multi-user virtual environments encourages a sense of presence in those users [26]. It also helps users to understand the persona of the other users, and facilitates social encounters with those users. Gerhard et al. go on to state the the form of the avatar has an influence over the level of presence felt. They carry out experiments comparing user reactions to different types of avatars, concluding that realistic or cartoon-like avatars are better at inducing presence than abstract shapes.

Within Agent Chameleons, agents are not constrained to one particular environment. They are capable of *migration*, moving between various different platforms, such as a robot, a mobile device such as a PDA, or a virtual environment. Within all of these environments the agents are considered to be embodied. We define the *embodiment* of the Agent Chameleon to be it's strong provision of environmental context, both individual and social. The agents have an embodiment within all environments, provided by the robot that they are controlling, or their representation within the virtual world. Within virtual environments, this embodiment is achieved by the provision of an avatar for the agent.

We define a *body-form* as a body that an agent can choose to adopt. This includes the form of any robots that the agents can occupy, as well as the agent's choices of representation within a virtual environment, on a desktop or on a mobile device. The body-form is limited by the abilities provided by the environment that the agent is occupying. It must, therefore, be provided by that

environment. Virtual agents have traditionally been confined to a single form of avatar, a single body-form. This research proposes a contrasting approach, our vision is of a system whereby an agent can mutate between various different body-forms.

The choice of body-form limits the agent’s capabilities as each has its own associated sets of capabilities. For example, the body-form of a robot is equipped with that robot’s sensory and motor capabilities. Within virtual environments, Agent Chameleons are provided with a library of different body-forms that they can adopt. Each of these body-forms also presents its own set of capabilities to the agent. For instance, a representation as a face may allow an agent to express certain facial expressions whereas a representation as a car will not. The ability to change body-form, therefore, enables the agent to expand its capability set by selecting the most appropriate body-form to it’s task. This act of changing body-form is referred to as *mutation*.

4 Identity

Identity is not a simple concept, and indeed the definition of identity, as it is used in both common speech and academic research, has expanded and changed over the years. Fearon, in an examination of this changing definition of identity, claims that it is currently seen as being either

“(a) a social category, defined by membership rules and (alleged) characteristics attributes or expected behaviours, or (b) socially distinguishing features that a person takes a special pride in or views as unchangeable but socially consequential (or (a) and (b) at once).” [27]

One important point to realise is that identity is primarily a social concept. As De Levita [28] noted, we present identity to others and have their identity presented to us. The question that defines identity is not, therefore, “Who am I?” but “Who am I in the eyes of others?”.

With the ability to change the body-form, the issue of identity becomes important. If the agent can change it’s form, how can the notion of that agent be maintained? This maintenance of identity is vital if the agent is to operate successfully. In order to do this, some understanding of the how humans perceive such identity is crucial.

We define an agent’s *identity* to be that which causes an agent to remain the same within the mind of the user. It is what remains constant for the agent, regardless of it’s chosen body-form. It should be noted that the identity of the agent is primarily a perception of the user.

This identity must be preserved across all body-forms that the agent can choose to adopt. In order to achieve this an agent has a number of features, called its *identity cues*, that remain constant across all body-forms, whenever possible. The relationship between the the identity and the embodiment is outlined in Fig. 1. The body-form is a feature of the environment, as the environment defines the types of body-forms that are possible. On the other hand, identity

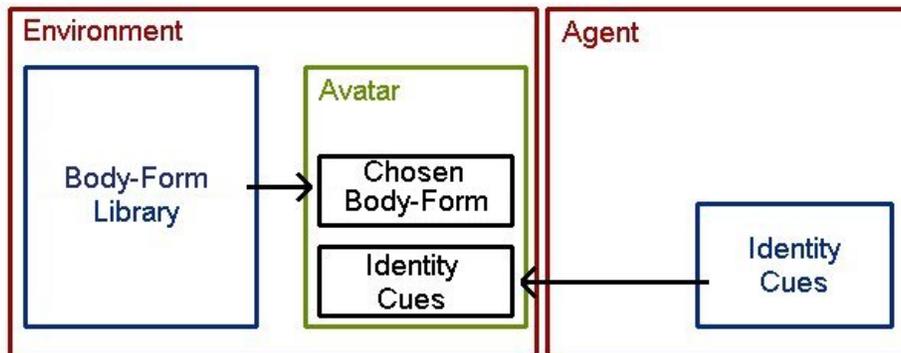


Fig. 1. The relationship between body-form and identity

and identity cues are features of the agent. Each agent has their own unique set of identity cues. When an agent is located within a virtual environment, the combination of its chosen body-form and identity cues is called the agent's *avatar*. The avatar is the agent's embodiment within the virtual world.

Despite the importance of understanding what underpins identity perception, the question of how a dynamic embodiment affects how one identifies an individual has, so far, remained unaddressed. There are a number of different factors that can be used as identity cues, including visual factors such as the colour scheme, markings on the body, or particular features common to all body-forms, such as eyes. Other possible identity cues include the type of character that the body-form represents (human, dog, insect) and non-visual factors such as the tone of voice used or the behaviour of the agent. The 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 should attempt to use the same identity cues.

5 Experimental Method

To investigate how identity cues can affect the users perception of a virtual agent's identity, and to look at which identity cues are more suitable, we devised a laboratory experiment. A random sample of volunteers were placed within a virtual environment and shown a virtual character. They were able to move around within the world and examine the character. This character was then replaced by three new characters, each with a different level of similarity to the original character. An example of this experimental setup is shown in Fig. 2. Participants were asked to rate "the degree you feel that each of these characters would be recognisable as the original character", giving each a score between 0 and 7. This was repeated a number of times within the experiment.

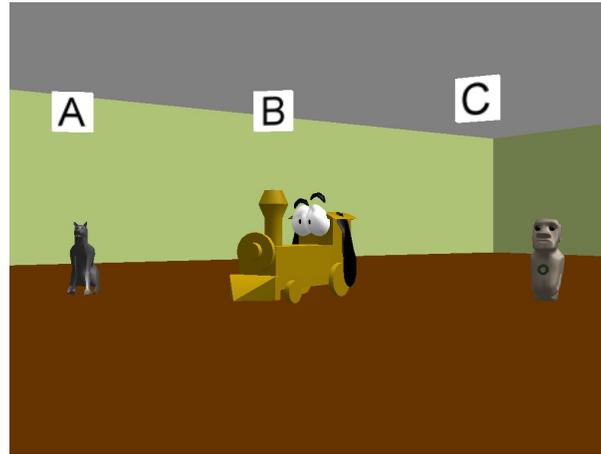


Fig. 2. Screen shot of the experimental environment.

As this is an initial experiment it was limited to characters located within a virtual environment. Additionally, the identity cues were limited to visual factors. A number of these cues were examined, specifically when:

- characters share a common feature, such as a hat or glasses.
- characters share a common colour scheme.
- characters share a common set of markings.
- characters are of the same class of objects, for example characters are both human, or are both dogs.

While this is not an exhaustive set of the possible identity cues, it is adequate for this initial investigation.

For each set of characters in the experiment each of the three characters shared only one identity cue with the original character. Additionally there were a number of characters that had no similarity to the original character which were used as controls. The test was carried out seven times for each participant, in a prescribed order. Each identity cue was repeated an identical number of times throughout these tests. Two examples of the character combinations are shown in Fig. 3. In the first (the kangaroo) where A has a common feature (i.e. boxing gloves), B has the same markings and C is a control. In the second (the wasp) A maintains colour, B is a control and C is the same class of character.

Participants were also asked some demographic questions, such as their age and gender, as well as being asked to rate their familiarity with both technology in general and computer games in particular.

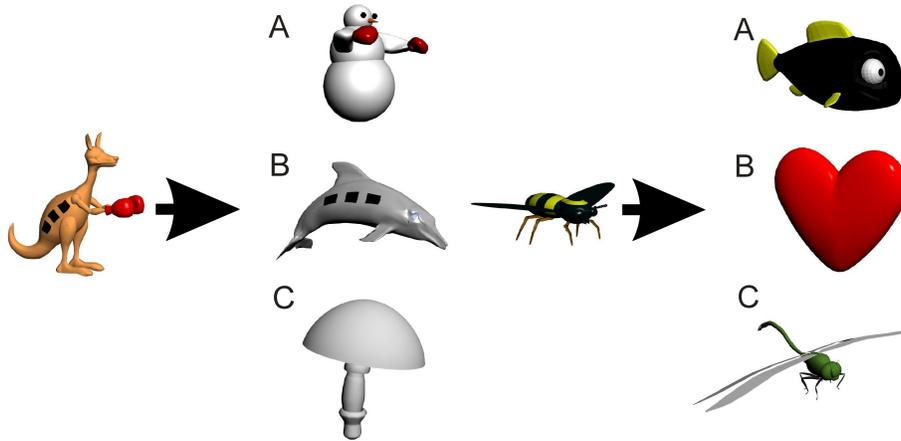


Fig. 3. Two sets of sample characters from the experiment.

6 Results

The experiment was carried out with a random sample of 31 individuals, 13 males and 18 females, aged between 8 and 50, with an average age of 23. Most participants were students. The average score, out of 7, for the question of “receptiveness to technology” was 4.90, and the average score, again out of 7, for the question of “familiarity to computer games” was 3.83.

Table 1. ANOVA Summary Table

Source	df	SS	MS	F	<i>p</i> -value
Identity Cues	4	69.93	17.48	38.97	0.00
Error	84	37.68	0.45		
Total	88	107.61			

Analysis of the results suggest that the mean similarity score, for each of the identity cues, is as shown in Fig. 4. In order to ascertain that this represents a statistically valid difference between the different identity cues, an Analysis of Variance (ANOVA) was employed. The ANOVA is a standard method of identifying a statistically significant difference between means. A one-way ANOVA (repeated measures) was carried out on the main independent variable, the similarity score. The results, as shown in Table 1, reveal a significant difference between conditions ($F(4, 84) = 38.97; p < 0.001; MSE = 0.45$). Post-hoc analysis suggested that, with a significance level of 0.001, the four different identity cues were significantly different from the control case. Thus we can claim that

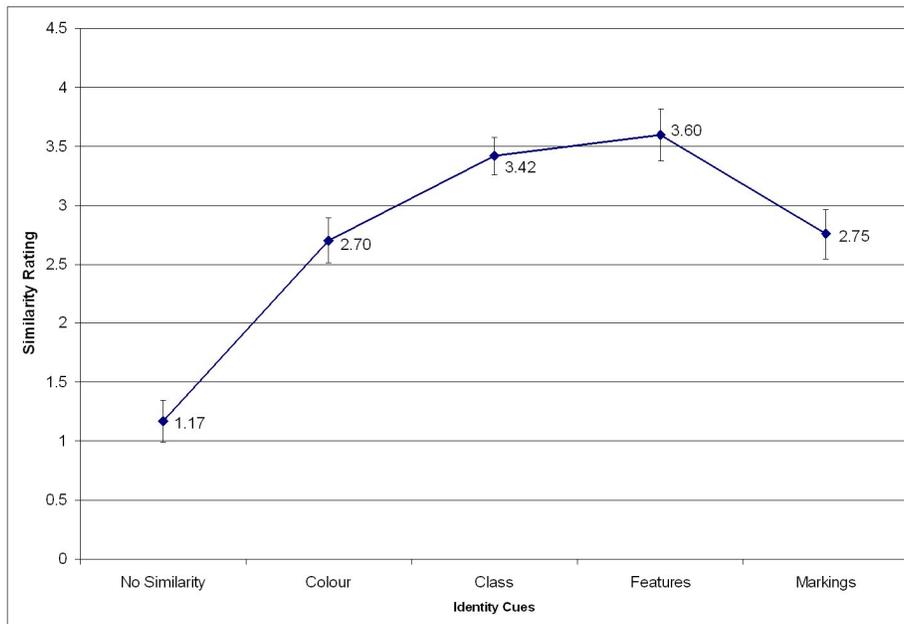


Fig. 4. The mean similarity score for each of the identity cues, with standard error indicated.

the inclusion of identity cues affects the user’s perception of the character’s identity. Additionally, with a significance level of 0.05, the use of common features is significantly better than the use of colours and of common markings.

A few observations need to be made about these results. Considering the results for colour, the choice of colour used clearly has an influence. When the colours used were black and yellow (the wasp’s colours, as is Fig. 3) a much higher rating was observed, with a mean score of 3.68, on the other hand when a less vivid green and blue combination was used, the rating was much lower, having a mean score of only 0.97, below that of the control characters. Furthermore, the maximum mean score for the identity cues is approximately 3.5, out of a maximum score of 7. While this is significantly better than the control cases, it is possible that this can be improved upon using a combination of identity cues. This experiment was by design limited to purely visual identity cues. One would imagine that the inclusion of non-visual cues, such as the tone of voice or the behaviour of the agent, would also have an effect. Later experiments will evaluate this.

When the results were further analysed in relation to the gender of the participants, their level of technological familiarity and their level of games playing, no significant differences were discovered. Despite this females have a consistently lower mean than males, as graphed in Fig. 5. This is consistent with findings into

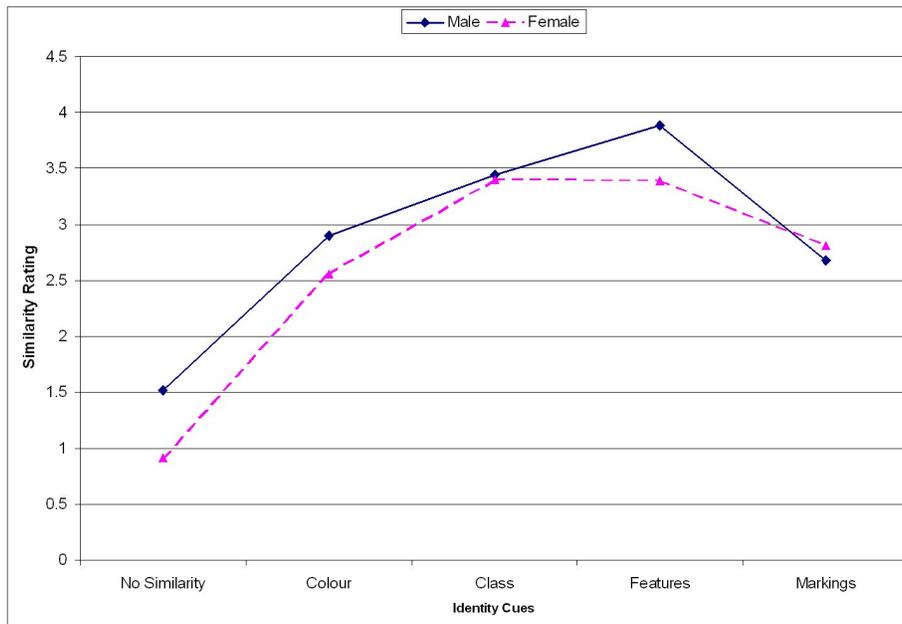


Fig. 5. The mean similarity score for males and females.

gender differences in visuo-spatial reasoning [29]. While no factors presented a significant difference, there are a number of factors that have yet to be examined. For example, will a child present different results than an adult?

7 Conclusions and Future Work

When virtual agents are equipped with dynamic embodiment, that is the ability to mutate their form, they are afforded the ability able to take advantage of an expanded set of capabilities. However, this presents problems with the agent’s identity and specifically how this can be maintained in the mind of the user.

Maintaining visual identity cues that transcend such avatar transmutation is of paramount importance. This paper has explored this very issue and has formulated and conducted experiments that offer an understanding of visual enablers for the maintenance of agent identity. From the statistical analysis of our experimental data, it can be concluded that the use of identity cues does indeed provide a valid method of maintaining an agent’s identity when its embodiment is dynamic. Furthermore, it has been shown that the use of common features produces a higher level of identity than the use of common colours and markings. The Agent Chameleons must be equipped with these identity cues to order to aid the user in their identification as the agent migrates from the virtual environment to the physical such as to a robot or a PDA.

This work raises a number of questions that are yet to be answered. These include how other identity cues affect the result. Can auditory or behavioural consistency increase the user's perception of the agent, or can a combination of visual cues achieve this? Additionally, more questions are raised regarding the choice of colours that can be used for an identity cue, specifically what choices are appropriate and which are not. More experiments must be carried out in order to answer these questions.

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