A User Study on Visualization of Agent Migration between Two Companion Robots[1]

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Abstract. In order to provide continuous user assistance in different physical situations and circumstances, it is desirable that an agent can maintain its identity as it migrates between different physical embodiments. A user study was conducted, with 21 primary school students which investigated the use of three different visual cues to support the user's belief that they are still interacting with the same agent migrating between different robotic embodiments.

Keywords: Agent Migration, Robot Companion, Human-Robot Interaction.

1 Introduction

The limitations of a specific robotic embodiment often constrains its functionality within a particular environment [1], [2]. Changes in the robot's embodiment to achieve a new desired functionality are often impossible (e.g. changing the size of the robot or changing from a humanoid to a mechanical appearance). As robots become more commonplace they may assume the role of butler, assistant, or companion. They will need to learn about their users, and their preferences, habits and living conditions in order to assist them. Rather than 'training' and familiarizing the user with a number of different robots, it may be desirable to use a single 'character' (or 'personality') of the robot and migrate it from one embodiment to another as required. Here we define the 'personality' of a robot as those features that persist and make it unique and recognizable from the owner's perspective (and that can be encapsulated in a software agent).

For example, it is not always feasible to transport larger scale robots, so being able to migrate a personalized companion robot [4] personality (agent) to a smaller embodiment (e.g. a handheld device) may allow the agent to travel with the user. With different robot embodiments the agent is less constrained to a particular information space [1] and may provide continuous assistance by accompanying the user [8]. By interacting with the user in different embodiments, the agent may also be able to achieve a stronger sense of contextual and situational awareness [6] of the physical and social environment, and improve the agent's understanding of, and

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relationship with, its user contributing to a sense of companionship for the user independent of the agent's specific embodiment.

An important aspect of agent migration is the ability for the agent to maintain its identity [7] and the user's belief that they are still interacting with the 'same agent' in different embodiments (e.g., as it migrates from a humanoid robot to a zoomorphic robot platform). We believe a first step in achieving user believability is through the *visual realization* of migration to reinforce the agent's identity and character across different embodiments. In order to achieve a visual realization of migration, we first need to understand users' mental models of agent migration. If users have no concept of their companions (software 'personalities') being able to move between different physical bodies, then they may e.g. mistake the visual process of migration as a form of communication between two robots (e.g. one robot requesting another robot to perform a certain task).

A user study was conducted with the aim of exploring participants' thoughts and feelings regarding robot-to-robot agent migration. The main objectives were to understand participants' mental models of the migration process and to determine the key components that help companion agents express convincingly the migration process through non-verbal (visual) cues.

2 Methodology

The user study took place in July 2008 with 21 primary school student participants all boys aged 11 to 14. A Pioneer and a PeopleBot robot (by MobileRobots Inc. with added custom hardware extensions, see Fig. 1) were equipped with LED panels to display three different visual cues to visually indicate the agent migration process:

Moving Bar – the panel light array at the agent's departing platform emptied, while the panel at the agent's arrival platform was simultaneously filled up over a period of 30 seconds.

Moving Face – a smiley moved from the bottom to the top of the panel of the agent's departing platform and then jumped to the top of the agent's arrival platform display panel and moved to the bottom of that panel to signify completion of the migration process over a period of 20 seconds.

Flashing Lights - the display panel at the agent's departing platform flashed initially slowly, but increased in frequency every 2 seconds. After 9 seconds, the display panel at the departing platform stopped flashing while the display panel at the agent's arrival platform started flashing at the highest flashing rate but slowly decreasing in frequency every 2 seconds and finally stopped flashing to signify completion of the migration process. This process took 18 seconds.

Note, these three conditions represented different modalities to visualize migration of the agent's 'personality': geometrical (Moving Bar), iconic (Moving Face) and temporal (Flashing Lights), see Fig. 1.

A Video-based Human-Robot Interaction (VHRI) methodology was employed (cf. [3, 5]) using three identical videos, except for the agent migration episodes which showed one of the three different visual cues. The videos were produced in the University of Hertfordshire Robot House, living room and kitchen areas. The scenario started with the user asking his companion (software agent), which was residing in a PeopleBot (the tall robot in Fig. 1), to fetch him a cup. The companion realized that the cup was located in a low profile cupboard , and so decided to migrate to the Pioneer robot (the short robot in Fig.1) in order to use its more versatile arm. The PeopleBot then entered the "Migration Portal" (a specific physical location) where the Pioneer robot was located. The companion agent (the robot's 'personality') then migrated and took control of the Pioneer, which then fetched the cup and placed it on the PeopleBot's tray. The companion then migrated back to the PeopleBot, which then handed the cup to the user.

Fig. 1. The three different visual cues used in the trial, from the left to the right – Moving Bar, Moving Face and Flashing Lights.

Procedure. The participants were divided into three groups, each assigned to one of the three visual cue conditions (i.e. Moving Bar, Moving Face or Flashing Lights). The participants' background information, including favorite subjects in school, hobbies and experience with computer games (i.e. Transformers, The Sims, Legend of Zelda, etc.) was collected by means of a questionnaire. To explore participants' mental models of agent migration, we used a short open-ended questionnaire to obtain a wide range of responses after each phase:

Phase 1: Each group was shown the entire scenario with only one of the three migration visual cues without explanation as to what was occurring. They were then shown just the same migration scenes again (i.e. agent migrating from PeopleBot to Pioneer and back to the PeopleBot) and then asked what they thought had happened during the migration scenes.

Phase 2: The experimenter then explained to the participants that the companion was actually migrating from one robot body to another. The participants then watched two videos showing the two remaining visual cues used to signal migration. They were then asked to indicate their preferred visual cue and explain their decisions.

3 Results

For Phase 1 a qualitative analysis classified responses into three categories – Communication, Migration and Energy Transfer (see Fig. 2). Explanations suggested that participants mostly considered the interaction between the robots (migration visual cues) to be communication. The Moving Face condition was most effective for displaying the process of migration to an uninitiated audience.

Phase 2 – The sample preferred the moving face and changing bar signals (see Fig. 3a). However, a significant difference was found related to the initial cue that the groups had been exposed to. The groups that had been initially exposed to the moving bar and flashing light signals preferred the moving face more than participants that had initially been exposed to the moving face signal (see Fig. 3b).

Fig. 4 indicates that participants who preferred the changing bars, referred to the analogous way in which the bars communicated the process of migration. Participants who preferred the moving face referred to speed as well as the ability of the face to communicate additional information.

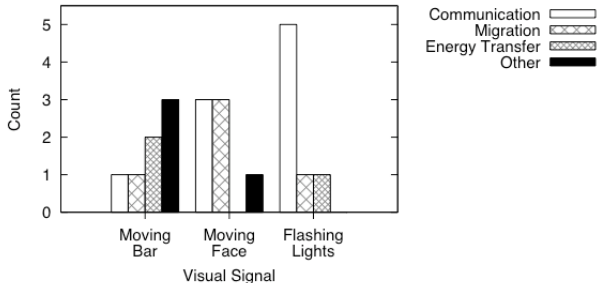

Fig. 2. Classification of participants' responses with regard to the three visual cues into 4 different categories.

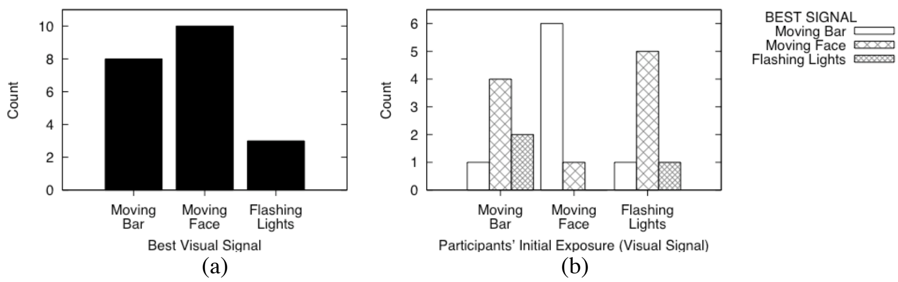

Fig. 3. (a) Participants feedback with regard to the best visual cues for expressing the migration process, (b) Categorization of participants from Fig. 3a based on their initial exposure.

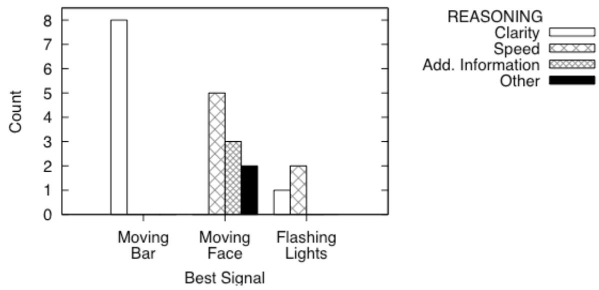

Fig. 4. Reasoning behind participants preferred visual cues.

4 Discussion

Our participants (primary school students) have a mental model for artificial personalities migrating between different physical embodiments. Also, the visual cues for agent migration highlight the idea of a personality migrating from one embodiment to another, and seem to reinforce the agent's identity and character in the new embodiment after migration. This is an important finding for our research. Our focus is to use the agent's personality as the main vehicle of identity rather than using identity cues from the embodiments as proposed by Martin et al. [7]. We believe that agents should be able to share embodiments, and it may not be possible for a physical robot to change its appearance on the fly if inhabited by different personalities. One might argue that the various habitants of the robot could use different colour schemes on the display panel as visual identity cues, this does not guarantee that different personalities will not share the same visual cues.

The Moving Bar and Moving Face were rated by the participants as the best visual cues to represent the realization of agent migration. The Moving Bar visual cue may be a spatial analogy to the process of migration, where one display empties as the other fills up (illustrating a connection between the two robots). The Moving Face visual cue shows the agent identity, symbolized by the face, moving from one robot to another robot. Additional information could be expressed through facial expression (although not implemented in this trial). Feedback for the Moving Face visual cue also indicated that the duration of the migration process was important for user acceptability of agent migration. More studies need to be conducted to verify and expand these findings. We are currently conducting the same study with adult participants and the new findings will be published in the near future.

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