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Brian Mac Namee
Dublin Institute of Technology, brian.macnamee@dit.ie

John Kelleher
Dublin Institute of Technology, john.d.kelleher@dit.ie

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Brian Mac Namee and John D Kelleher
DIT AI Group, Dublin Institute of Technology,
Kevin St, Dublin 8, Ireland
{Brian.MacNamee|John.Kelleher}@comp.dit.ie

Abstract

Mixed-reality virtual agents are an attractive solution to the problems associated with human-robot interaction, allowing all the expressiveness of virtual characters to be married with the advantages of a physical artifact which exists in a shared environment with the user. However, common approaches to achieving this restrict the virtual characters appearing on top of, or encompassing the robot. This paper describes the *Stepping Off the Stage* system in which mixed-reality agents are allowed to step off the robot stage and move to other parts of the environment, offering compelling new interaction possibilities.

Keywords: Mixed reality, robotics, human-robot interaction, intelligent virtual characters

1 Introduction

Because human interactions with robots must be fundamentally different from our interactions with more mundane machines there has been considerable research effort put into making interactions with robots more engaging (for a good overview see (Fong et al., 2003)). However, it is difficult to build hardware devices capable of the subtleties of expression required for engaging interactions. To overcome these difficulties, animated virtual agents displayed on screens mounted on robots are used as interfaces (Bruce et al., 2001). However, this approach denies the user the opportunity to share an interaction space with the virtual agent and has been found to be limited in terms of the level of engagement that is achieved.

More recently *mixed-reality* approaches have been used. In this approach, users view robots, and their environment, through viewing devices that allow the robots to be augmented with virtual agents which appear to sit on top of or encompass them (Dragone et al., 2007). This marries the expressive capabilities of a virtual agent with the advantage that the user and the agent share a common physical interaction space.

The question posed in this paper is: *why restrict the virtual agent to acting as an interface to the robot?* In many application scenarios - such as guiding, tutoring or selling - it is more appropriate to treat the mobile robot as a vehicle that a virtual agent can use to move around an environment and then, when appropriate, step off the robot stage and interact with other artifacts. The remainder of this paper will describe the *Stepping Off the Stage* (SOTS) system which has been developed to achieve this.

2 The Stepping Off The Stage System

The SOTS system is based on the metaphor of virtual agents moving between *stages*. When an agent moves from one interaction area to another it is said to step from one stage to another. On moving to a new stage the agent is informed of the physical limitations of the area in which it can now operate, and the kinds of behaviour that are now suitable (as this can differ greatly from one stage to another).

The high level architecture of the SOTS system is shown in Figure 1. The *Stage Manager* is at the centre of the architecture, and is responsible for managing all objects within the execution environment. Its key tasks are: determining the availability of stages to agents through the

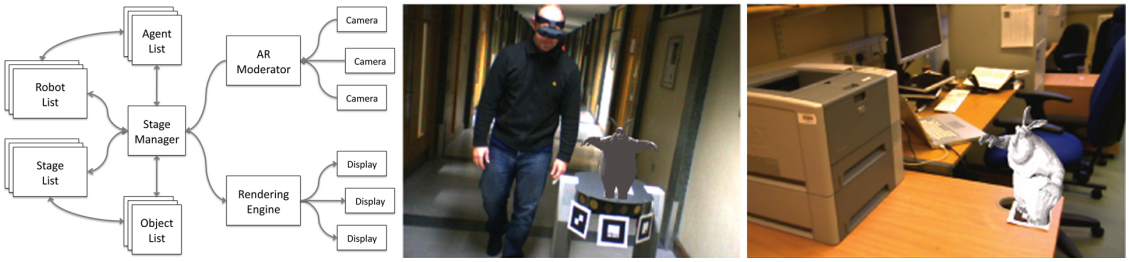

Figure 1: The SOTS architecture; a SOTS agent being followed by a user; and describing a printer.

recognition of fiducial markers, which is performed by the *AR Moderator* using the the open source API ARToolkit; summoning robots as requested by agents; managing agents whose behaviours are driven using a combination of finite state machines and the *role-passing* technique of Mac Namee et al. (2003), which is based on *situational intelligence* and allows agents behave believably in a wide range of different situations; and informing the *Renderer* which virtual augmentations should be drawn. The remaining components of the architecture store lists of the key protagonists in a SOTS execution environment, namely: *objects* (which can be both real and virtual), *stages*, *character agents*, and *robots*.

To demonstrate the SOTS system a working prototype has been implemented in which a new employee arriving on the first day at their new place of work is greeted at the foyer by Pixel the virtual rabbit who guides the employee to their new office and instructs them in how to use their new office equipment. Screenshots of this prototype are shown in Figure 1. In these images Pixel is shown being followed by the user, at which time Pixel inhabits the robot-top stage (this image is a composite generated to illustrate both the user and what they see); and telling the user all about their new printer, at which time Pixel inhabits a desktop stage. This basic prototype demonstrates all of the components of the SOTS system working together.

3 Conclusions & Future Work

The work described in this paper begins from the position that mixed-reality characters offer a very attractive solution to solving the problem of human-robot interaction. However, there is no need to stop here. By adopting the metaphor of stages, and using the technique of role-passing, SOTS agents can step off their robotic stages and into the user's environment to offer new engagement interaction possibilities. In the near future we intend to improve this work through the addition of improved rendering, more interactive characters, and a more elaborate application scenario. All of this work is moving towards a larger goal of a creating a mixed reality character that appears to share environments with human users.

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