The Perceptive Puppet: Seamless Embodiment Exchange Between Real and Virtual Humans in Virtual Environments for Training

Andrés Saraos Luna, Valérie Gouranton, Thomas Lopez, Bruno Arnaldi

The Perceptive Puppet:
Seamless Embodiment Exchange Between Real and Virtual Humans in Virtual Environments for Training

Andrès Saraos Luna, Valérie Gouranton and Bruno Arnaldi
INSA de Rennes, 20, Avenue des Buttes de Coësmes , CS 70839, 35708 Rennes, France
IRISA / INRIA, Campus de Beaulieu 35042 Rennes Cedex
{*Andres.Saraos_luna, Valerie.Gouranton, Bruno.Arnaldi*}*@irisa.fr*

Keywords: Teamwork, Virtual Environment, Embodiment, Training.

Abstract: We present a novel mechanism that allows real and virtual humans to dynamically exchange the control of their embodiment in virtual environments. Such a mechanism raises two important issues: the possibility of dynamic embodiment exchanges between real humans and virtual humans and the continuity of actions of the team members after an exchange. To address these issues we introduce a new entity, the Perceptive Puppet that abstracts real and virtual humans into one common entity containing its own knowledge.

1 INTRODUCTION

In Collaborative Virtual Environments for Training (CVET), a group can learn and practice the completion of a task as a team using all the assets provided by Virtual Reality: low cost and risk-free for the trainees, no need for costly physical equipment, the possibility to repeat the task as many times as necessary and the trainees' progress can be saved and used later on for further analysis (Boulanger et al., 2006). Another main asset is the introduction of virtual humans in the team training, as replacements for missing team members and as collaborators working with the trainees. They can act as collaborators that contribute to the completion of the task, teachers that guide and provide contextual help whenever they are needed or even troublemakers that challenge the trainees. All these different roles are classified in two main groups (Sycara and Sukthankar, 2006): an equal team member or an assistant to either the team as a whole or just one particular individual.

In this paper we provide a mechanism that allows real and virtual humans to exchange their embodiments during the simulation. Such a mechanism offers new usages for both designers and users of CVETs. Industrial applications of VR training go from maintenance procedure (Gerbaud et al., 2008) to military applications (Fonseca et al., 2011). To further illustrate this claim let us use an illustrative scenario in industrial training. We consider various groups of two workers trainees that are learning how to operate a machine. In each group, one of the team members is a real human, the other one is a virtual one. The actions of all groups are being monitored by an expert trainer who is not embodied in the virtual world. The trainer can take over the control of the virtual coworker's embodiment and monitor the on-going work directly in the field. From there, the trainer has various options:

- if the trainee cannot operate correctly, the trainer can take over the control of the trainee's embodiment in order to move forward with the procedure before letting the trainee continues, now back on his tracks.
- if the trainee has trouble achieving his tasks, the trainer can help him by directly collaborating with him in the virtual world as his coworker.
- if the trainee is doing well, perturbations can be added to test his adaptive capabilities.

The trainee does not need to know that the control of his coworker is being swapped, the whole process is transparent for the trainee. This allows the trainer to play a more active role in its teaching, while giving him more flexibility to test the trainees capacities. Furthermore, the trainer can adapt its implication depending on the level of each trainee. Similar scenarios can be described for Medical Training (Gallagher and Cates, 2004; Kunkler, 2006) and Emergency Training (Dugdale et al., 2004) applications.

Our contribution proposes an exchange mechanism by addressing: (1) an abstract representation of real and virtual humans, (2) knowledge management. In section 2 we investigate previous work. In sections 3 and 4 we present our exchange mechanism along with our current implementation before concluding in section 5.

2 RELATED WORK

Our review of related work focuses on how the users and their virtual teammates are modeled, and how the knowledge is handled in existing work (CVET).

2.1 Users in CVETs

In the COVET (Oliveira et al., 2000) application and in most medical collaborative training applications, only one person can interact. Others are spectators and learn the procedure. Each one is confined in its initial role during the simulation.

The GVT[1] (Gerbaud et al., 2008) platform allows collaborative training between real and virtual humans. The trainees do not have direct control of their embodiments. This system could allow the users to pass on their commands to a different embodiment during the simulation and thus perform an effective exchange. However, it does not allow users to interact directly with their environment thus simplifying the process.

For the MASCARET (Buche et al., 2003) model, implemented in the SecureVI application, the user collaborates with virtual humans by collecting their knowledge and giving them orders. A trainer oversees the training without being incarnated in the virtual world. He has the possibility to play the role of a working virtual human and act in its place. Although this represents a first step to a full-fledged exchange mechanism, only the trainer has this ability, virtual humans cannot initiate an exchange nor can the trainee.

Our analysis shows that the possibility of an exchange between users has not been addressed thoroughly. Also we did not find an existing model that gives both real humans and virtual humans a common point of entry to the virtual environment that could be exchanged at will.

2.2 Knowledge Base

Sycara et al. (Sycara and Sukthankar, 2006) describe various theories that aim to depict team knowledge in teams, mixed with real and virtual humans. This has been the subject of relatively few research.

Among them, an interesting approach is the shared mental model theory. According to the psychology and cognitive science literature (Klimoski and Mohammed, 1994), people use internal representations of the world to understand and act upon it. They serve as reasoning mechanism that exists in a person's mind and allows to predict, reason and form explanations of his surrounding environment.

One popular trend in teamwork related work is the notion of a shared mental model used to improve team performance (Jonker et al., 2010; Mathieu et al., 2000). This theory is notably used in multi-agents context (Yen et al., 2006).

None of the existing CVET has an implementation of team knowledge with mixed teams. The way knowledge is handled is central to allow continuous actions after an exchange is performed. One convenient and often used way to include the knowledge is to grant virtual humans with omniscience over the whole environment, and assume the real users know the procedure beforehand. This is how most CVETs, including Dugdale's fire simulation training (Dugdale et al., 2004) and GVT (Gerbaud et al., 2008) handle the knowledge of their virtual humans. Omniscience, for real or virtual humans, is a very strong and not realistic assumption because they are not supposed to have the same access to a full knowledge base.

2.3 Synthesis

We review the key points of our analysis of existing work. None of them successfully implements an exchange mechanism that would allow the scenarios described in our introduction to be used. Real humans and virtual humans are always considered as separate entities and therefore interact with the virtual world through different channels, making a generic control exchange mechanism difficult. The continuity of actions may be achieved through omniscient agents although the mechanism has not been tackled on directly. However there is a lack of a distributed approach that does not assume that the real humans also have the privilege of omniscience.

3 THE PERCEPTIVE PUPPET

The objectives of our contributions are: (1) the definition of an abstraction of the team members encompassing both real and virtual humans, (2) the construction of a model, independent from the nature of the team member, that allows the continuity of actions

[1] Generic Virtual Training - http://www.gvt-nexter.fr/

after an exchange is performed, (3) the formalization of the exchange process.

For this purpose we introduce the Perceptive Puppet, an abstraction (section 3.1) encompassing both real and virtual humans that combines an interaction model (section 3.2) and a knowledge base (section 3.3) to address the issues an exchange mechanism rises (section 3.4).

3.1 Concept

We introduce a specific element, the Perceptive Puppet (Fig. 1). It serves as a mediator that connects together the real or virtual humans and the virtual world. The Perceptive Puppet serves as a gateway unifying the actions sent by the team members and relaying the knowledge acquired from within the virtual world. However, it is deprived of any kind of decision process and cannot interact in the virtual world without some puppeteer pulling the strings. The team members thus act as puppeteers taking control of their respective Perceptive Puppets to act upon the virtual world. As the acquired knowledge is independent from the controlling team member, they benefit from the perceptive capabilities, the knowledge base and the interactive abilities of the Perceptive Puppet they are controlling as a base to their decision process.

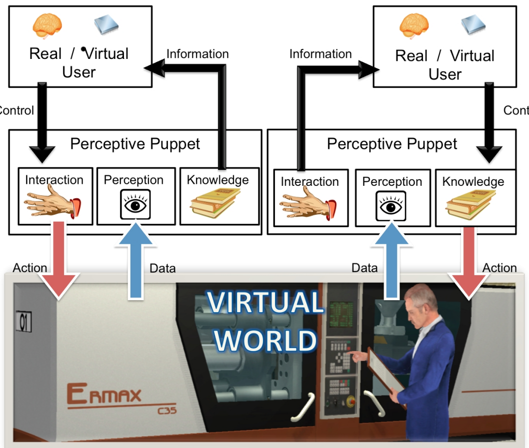

Figure 1: The relation between the team members, the Perceptive Puppet and the Virtual World.

A Perceptive Puppet is composed of two main parts: (1) an Interaction model that describes how the Perceptive Puppet interacts with the virtual world and how it can be controlled by a real or virtual human, (2) a Knowledge base fueled by the perceptive capabilities of the Perceptive Puppet. The knowledge is independent of the real or virtual human that controls it.

With the Perceptive Puppet, an exchange of embodiment between real and virtual humans is defined as an exchange of control over the real and virtual humans' respective Perceptive Puppets. As the Perceptive Puppet contains its own knowledge base at the real and virtual humans' disposal, the controlling real or virtual human can gather data about the actions previously undertaken by the Perceptive Puppet and carry them on.

3.2 Interaction Model

Our goal with the exchange mechanism is to allow any team member to exchange their Perceptive Puppet with another one. The interaction model has to take into account that: (1) each team member takes control of a Perceptive Puppet, (2) the Perceptive Puppet interacts with other objects, (3) objects can interact with each other.

We defined an interaction model, called Collaborative-STORM (Saraos Luna et al., 2012) that is an extension of the STORM model (Mollet et al., 2007) and therefore shares the same core mechanics. The STORM model links together behavioral objects, composed of internal behaviors and a set of communicating interfaces, that are interacting with each other. The combination of an internal behavior and a communication channel is called a capacity. A relation is defined as a link between objects that are in interaction through matching capacities. The models are a complete solution to design complex behavioral objects and complex interactions between such objects in virtual environments.

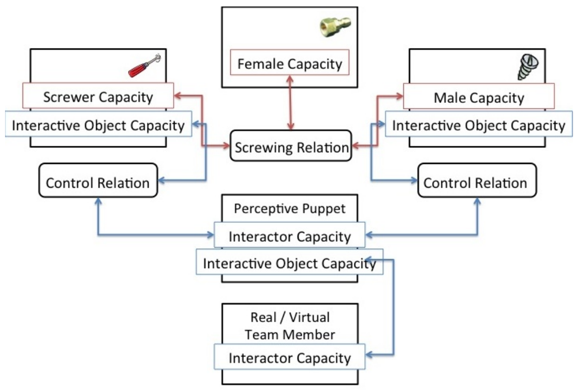

Figure 2: Collaborative-STORM Example: a team member, either real or virtual, is controlling a Perceptive Puppet in the virtual world. Through the Perceptive Puppet, it controls a screwdriver and a screw. He then can trigger the screwing relation by using these objects with a female plug

The Collaborative-STORM model introduces a new relation, the Control Relation that allows one object to take control of a set of parameters of another object. In this way, one object could take control of one or several properties of another object. Our addition to this model is the definition of the Perceptive Puppet as an object controllable through the Control Relation. This mechanism allows the team members, modeled as a Collaborative-STORM object, to take control of a Perceptive Puppet. The Perceptive Puppet can in turn interact with other objects of the environment (Fig. 2).

3.3 Knowledge Base

After an exchange, any team member, real or virtual, need to be able to pursue the actions of the previous owner of the Perceptive Puppet he now controls. It needs to have an understanding of what was the previous team member's actions and goals using the Perceptive Puppet knowledge, self-contained and independent of its controlling entity. The knowledge base of the Perceptive Puppet needs to be compatible and usable by all team members, particularly the real humans. This knowledge needs to be accessible so that all team members, especially real humans, can find relevant information in the Perceptive Puppet's knowledge base.

The perceptive abilities of a Perceptive Puppet are its main source of information. It is composed of two parts: the Sensory Channels and the Filter Pipeline. The Sensory Channels acquire data from the virtual environment through perceptive abilities such as vision or sound. The Filter Pipeline then filters the data according to various criteria such as relevance, spatial proximity or usefulness in the current task.

By giving the Perceptive Puppet its own knowledge and perceptive abilities, we assure that the data gathered is independent of the controlling team member. This assures us that when an exchange is performed, the knowledge of the Perceptive Puppet remains consistent.

3.4 The Exchange Protocol

We formalize the usage of an exchange of embodiments in a dedicated protocol that handles how the exchanges of Perceptive Puppets are performed. When a team member wants to take control of another Perceptive Puppet, the protocol ensures the transaction can be done before performing the exchange.

The acceptance conditions are fully customizable as they are platform and application dependent. The protocol specifies who can initiate an exchange and if virtual humans are allowed to be the instigators of an exchange or not. From another point of view, a trainer should always be able to initiate an exchange with a trainee, even without warning him. It is the trainer's decision whether an exchange can benefit the trainee's training.

The protocol also specifies the situations in which an exchange is acceptable. Indeed, team members may not be authorized to engage in an exchange while they are performing an action.

4 IMPLEMENTATION

In this section we provide an implementation of the embodiment exchange in an existing CVET, the GVT platform. We chose the GVT platform because its latest version allows collaborative teamwork between real humans and virtual humans. The GVT architecture mainly contains three engines: (1) the Scenario engine that describes the step by step procedure the team has to realize, (2) the Interaction engine that contains the environment composed of various behavioral objects, it follows the Collaborative-STORM model and (3) the Humanoid engine that handles the humanoid representation of the participants.

The Perceptive Puppet is added to the GVT platform as an object of the environment. It is implemented between the team members and their humanoid representation. Each team member will control a Perceptive Puppet that will in turn control an humanoid representation in the virtual environment. We describe the implementation of the Perceptive Puppet in section 4.1, the exchange protocol in section 4.2 and our test scenario used to validate our concept in section 4.3.

4.1 Perceptive Puppets

The architecture proposed to implement the Perceptive Puppet (Fig. 3) is composed of three main parts:

- Each team member, virtual and real, is linked to the Perceptive Puppets he controls.
- The Environment Interface (perception and interaction) is the link between the virtual environment and the Perceptive Puppet.
- The Knowledge Base encompasses all the knowledge base of the Perceptive Puppet.

We break down into three components: a perceptive model, a knowledge base and an interaction model. The first two ensure the continuity of actions after an exchange is performed, the last one gives real and virtual humans the ability to perform an exchange.

Perception: the Perceptive Puppet perceives its environment through a number of sensory channels.

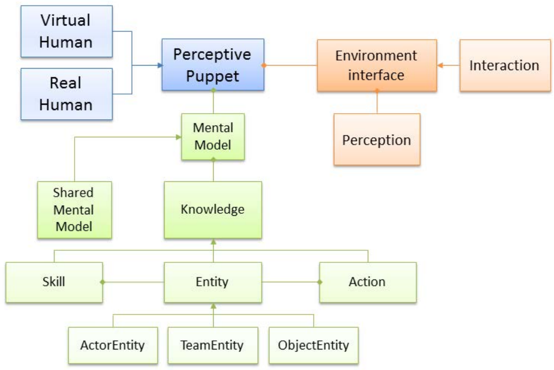

Figure 3: Architecture Implementation.

In our implementation, only a basic line of sight through ray tracing is implemented. The acquired knowledge is filtered by a pipeline of filters in order to only retain the information deemed important by the Perceptive Puppet. The filtered knowledge is then dispatched to the knowledge base.

Knowledge: part of the knowledge is task-specific, such as the actions and tasks that are possible or required by the simulation. Others, like the position of objects and teammates and the team members' skills, are more generic and can be reused in different simulations. In our implementation, we take advantage of the GVT platform scenario engine to fuel the action related knowledge base of the Perceptive Puppets. The Perceptive Puppet stores knowledge about entities that are perceived through their sensory channels, for example storing the name of the object and the last time they have seen it. If an already known object is sighted, the time stamp is updated.

Interaction: an interaction relation is implemented as a GVT relation. The relation links Interactors (object that can take control of other objects) and Interactive Objects (objects that can be controlled by others). Once the relation is established, it passes on the commands and parameters from the Interactor to the Interactive Object. The Perceptive Puppet is implemented as a GVT object with the Interactive Object capacity. Real and virtual humans both control the Perceptive Puppet through this channel.

4.2 Exchange Protocol

The exchange protocol is encapsulated inside a dedicated GVT relation. This relation links two GVT objects disclosing the Exchange Capacity, and handles the exchange of control. The Perceptive Puppet is thus constructed as a GVT object containing amongst other capacities the exchange capacity. The current parameters are: virtual humans always agree to an exchange, virtual humans cannot initiate an exchange, real humans are asked if they want to perform an exchange and an exchange can be performed at any time.

During the simulation, a real human triggers the exchange relation by selecting another Perceptive Puppet. If the selected Perceptive Puppet is controlled by another virtual human, the exchange is performed right away. If a real human is controlling it, a pop-up window informs him of the exchange demand and he has the choice to either validate or refuse the demand.

4.3 Test scenario

Our test application consists of a team of five soldiers having to perform a specific procedure to open fire with their armored vehicle. They need to perform a serie of coordinated actions on various parts of the vehicle. Each soldier has a well-defined role that has to be handled by a real or virtual human.

At launch, the trainee is prompted to select a role to begin the scenario. He is then given control of the corresponding Perceptive Puppet and can perform his part of the procedure regardless of the nature of the other team members. The other roles, and the associated Perceptive Puppets, are controlled by virtual humans or by other trainees. The trainee is notified of any new knowledge the Perceptive Puppet gains through its perceptive ability. The Perceptive Puppets could see their environment and keep all the perceived knowledge in their knowledge base. All the objects contained in the knowledge of the team member's Perceptive Puppet are listed in a GUI window and the trainee can select a specific object to obtain detailed information about it such as the last time it has been seen or its last known location (Fig. 4).

At any time during its work, any team member can perform an exchange with another team member by selecting its Perceptive Puppet in the application. Once the exchange has been accepted, the Perceptive Puppet controls are exchanged between the two team members. He can thus continue the process in a brand new role by using the knowledge contained in the Perceptive Puppet. This test scenario successfully demonstrates the exchange mechanism at work.

5 CONCLUSION

We defined a new object, the Perceptive Puppet, that provides new issues: (1) an abstraction encompassing both real human and virtual human and (2) a set of tools to ensure the continuity of actions once an exchange is performed. The Perceptive Puppet mainly achieves this by acting as a mediator be-

Figure 4: User interface allowing Real Humans to browse the knowledge of the Perceptive Puppet it controls. The knowledge about the cannon is selected (A). The cannon is thus highlighted in the environment (B), and all the known data about it is displayed (C).

tween the team members, real or virtual, and the virtual world. The Perceptive Puppet and its controlling entity are connected through an interaction link that works the same way for real humans and virtual humans. Additionally the Perceptive Puppet has its own knowledge and perceptive channels, independently of any controlling team member.

Acknowledgments

This work was partially supported by the French Research National Agency project named CORVETTE (ANR-10-CONTINT-CORD-012) and by the OSEO project named FUI11 SIFORAS.

REFERENCES

Boulanger, P., Wu, G., Bischof, W., and Yang, X. (2006). Hapto-audio-visual environments for collaborative training of ophthalmic surgery over optical network. In *Haptic Audio Visual Environments and their Applications, 2006. HAVE 2006. IEEE International Workshop on*, pages 21–26. IEEE.

Buche, C., Querrec, R., Loor, P. D., and Chevaillier, P. (2003). MASCARET: pedagogical Multi-Agents system for virtual environment for training. *Cyberworlds, International Conference on*, page 423.

Dugdale, J., Pavard, B., Pallamin, N., el Jed, M., and Maugan, C. L. (2004). Emergency fire incident training in a virtual world. In *Proceedings ISCRAM2004*, volume 167.

Fonseca, B., Paredes, H., Rafael, L., Morgado, L., and Martins, P. (2011). A software architecture for collaborative training in virtual worlds: F-16 airplane engine maintenance. In Vivacqua, A., Gutwin, C., and Borges, M., editors, *Collaboration and Technology*, volume 6969 of *Lecture Notes in Computer Science*, pages 102–109. Springer Berlin / Heidelberg.

Gallagher, A. and Cates, C. (2004). Virtual reality training for the operating room and cardiac catheterisation laboratory. *The Lancet*, 364(9444):1538–1540.

Gerbaud, S., Mollet, N., Ganier, F., Arnaldi, B., and Tisseau, J. (2008). GVT: a platform to create virtual environments for procedural training. In *IEEE Virtual Reality*, pages 225–232, Reno Etats-Unis.

Jonker, C. M., van Riemsdijk, M. B., and Vermeulen, B. (2010). Shared mental models: A conceptual analysis. *Coordination, Organization, Institutions and Norms in Multi-Agent Systems@ AAMAS2010*, page 41.

Klimoski, R. and Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of management*, 20(2):403–437.

Kunkler, K. (2006). The role of medical simulation: an overview. *The International Journal of Medical Robotics and Computer Assisted Surgery*, 2(3):203–210.

Mathieu, J., Heffner, T., Goodwin, G., Salas, E., and Cannon-Bowers, J. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology*, 85(2):273.

Mollet, N., Gerbaud, S., and Arnaldi, B. (2007). STORM: a generic interaction and behavioral model for 3D objects and humanoids in a virtual environment. In *IPT-EGVE the 13th Eurographics Symposium on Virtual Environments*, volume Short Papers and Posters, pages 95–100, Weimar Allemagne.

Oliveira, J., Hosseini, M., Shirmohammadi, S., Cordea, M., Petriu, E., Petriu, D., and Georganas, N. (2000). Virtual theater for industrial training: A collaborative virtual environment. *Proc. 4th WORLD MULTICONFERENCE on Circuits, Systems, Communications & Computers (CSCC 2000), Greece*.

Saraos Luna, A., Gouranton, V., and Arnaldi, B. (2012). Collaborative Virtual Environments For Training: A Unified Interaction Model For Real Humans And Virtual Humans. In *International Conference on Serious Games and Edutainment*, pages 1–12, Germany.

Sycara, K. and Sukthankar, G. (2006). Literature review of teamwork models. Technical Report CMU-RI-TR-06-50, Robotics Institute, Pittsburgh, PA.

Yen, J., Fan, X., Sun, S., Hanratty, T., and Dumer, J. (2006). Agents with shared mental models for enhancing team decision makings. *Decision Support Systems*, 41(3):634–653.