NEXUS: Fusing the Real & the Virtual

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***Abstract* — The aim of this project has been to create NEXUS, a framework that supports fusion of the Physical and the Virtual, creating a single world in which people can interact with deliberative agents in their own space. This work promotes a more orthogonal perspective for the development of artificial systems and their functionality as tools. This NEXUS becomes a place in which virtual and physical information spaces become entwined, resulting in the entities that inhabit this space being able to interact in a seamless fashion. The level of interaction envisaged is not simply a matter of people controlling the form of a virtual space, or even one of artificial entities that control the form of a physical space. Instead, we view the NEXUS as a fusion of physical and virtual spaces in which a number of entities jointly interact. This then facilitates the coherent integration of humans and the digital information space.**

***Keywords* — Augmented reality, control architectures, multi-agent systems.**

I. Introduction

In this work, two basic perspectives often debated in research on the theory of mind becomes re-animated, namely the *dualist* approach where mind is distinct from body and the *embodied* approach where mind and body aim to function as one. Work to date has aimed with moderate degrees of success to bridge the gap between the two in artificial systems. While the work discussed in this paper reinforces a more dualist approach, it is argued that, while the debate where the integration of mind and body is clear for human cognition, it is not necessarily appropriate to be so constrained in artificial systems. As discussed in Duffy [1], there are and will always be fundamental differences between human and machine. While there are continuous endeavors to merge the two from many different perspectives, to remain constrained by a single interpretation of what a machine can be is not constructive. This highlights a fundamental distinction between a top-down approach to cognition, where the aim is to understand the human, and the bottom-up approach where the aim is to build highly sophisticated artificial systems. Traditionally the goals of the two have generally aimed to merge with a useful transference from one to the other of ideas.

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In industrial applications, the role of the machine as a tool is clear and their function relies and exploits the core properties of machines. Given that machines have a fundamentally different capability set, to constrain it to our capabilities is simply inappropriate. The issue becomes what could it do that exploits its inherent features? At a very basic level, are the human frames of reference of one-mind-one-body still valid in developing a reasoning machine's functional capabilities? This work illustrates an orthogonal approach which looks at what alternate ideas can be integrated into the development of sophisticated artificial systems.

Such projects as Agent Chameleons [2][3] aim to develop autonomous digital agent assistants which can act as a digital friend and move between embodied containers such as robots, virtual reality avatars and animated agents on desktops or PDA's. The NEXUS project [4] seeks to extend the functionality of such an agent by developing the reference of the agent being inherently linked to our reality. For example, gestures of an avatar in a VR space are fundamentally referenced in our physical reality. Similarly, the motion of the agent across numerous screens is based on realising a sense of mobility in physical space. The screen where we see the avatar represents a window through which the avatar can interact with us, not uniquely a window through which we can view the virtual space as is generally understood. The primary reference is the here and now, not something in some virtual space elsewhere.

The advantages of employing augmented reality strategies are clear with the provision of visually augmented information transfer to the user, uniquely tailored to the context of the physical environment. If not uniquely tailored, then it acts as a distraction from the real and consequently, the justification for its integration into our perception space becomes questionable. It is therefore paramount that this context is managed with a sufficient degree of sophistication that enables its successful implementation. It is for this reason that the deliberative reasoning mechanisms found in multi-agent systems approaches are employed, and specifically the Belief-Desire-Intention methodology [5] for agent development.

An intelligent NEXUS agent consequently seeks to dismantle traditional world boundaries. The virtual world is viewed as a mere extension of the physical and conversely the physical is viewed as an extension of the virtual.

Previous work has investigated the convergence of Multi-Agent Systems techniques and virtual and mixed reality systems. Expectations placed upon avatars and

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virtual entities demand high levels of visual reality, meaningfulness of interactions with the user [6] and behavioural plausibility. Bates introduced the need for believable agents [7] while Cybercafe research [8] characterized the avatar as an aggregation of a mind and body components. Recent research has embraced the notion of MAS in the provision of these important avatar characteristics [9].

The NEXUS project stands in contrast to this research in that it advocates the adoption of a BDI agent model to deliver the necessary deductive underpinning of plausible avatar behaviour.

The following sections introduce the NEXUS framework and its elements. This is followed by demonstrations that illustrate the integrative themes of merging these real and virtual worlds into one coherent information space. A discussion of the integration of real, virtual and augmented realities concludes the paper.

II. The Nexus Framework

The NEXUS Framework constitutes the NEXUS Space, a physical space that is imbued with microphones, touch sensitive screens, speakers, cameras (Logitech QuickCam Orbit), and location-sensing devices and, the NEXUS Architecture to support the integration of each of the required technologies and functionalities within this space. Fig. 1 depicts this architecture which is comprised of a stratification of three constituent technology layers. The underlying system consumes pre-existing of-the-shelf software systems with the innovation manifesting itself through the integration of these complex disparate software components.

The underlying agent apparatus is provided by Agent Factory [10] a cohesive framework that delivers structured support for the disciplined development and deployment of agent-based systems. Two key components namely, the Agent Factory Development Environment and the Agent Factory Runtime Environment respectively support the design and debugging of agents and the subsequent execution of these agents. Agent Factory agents adhere to the broad class of Belief Desire Intention (BDI) agents. The agent actuators call the Java 3D API, which acts as a high level interface for the DirectX API. We use Java 3D as it a natural way to interact with Java-based Agent Factory agents. In order to support video input and the sensing of events in the physical world, we utilise JARToolkit, developed by C-Lab, Germany [11], which is in effect a Java wrapper that in turn facilitates the use of ARToolkit, developed by Kato and Billinghurst [12]. Voice interaction is supported through the use of IBM ViaVoice which interfaces with the JavaSpeech API. Collectively this enabled the following mixedreality experiments.

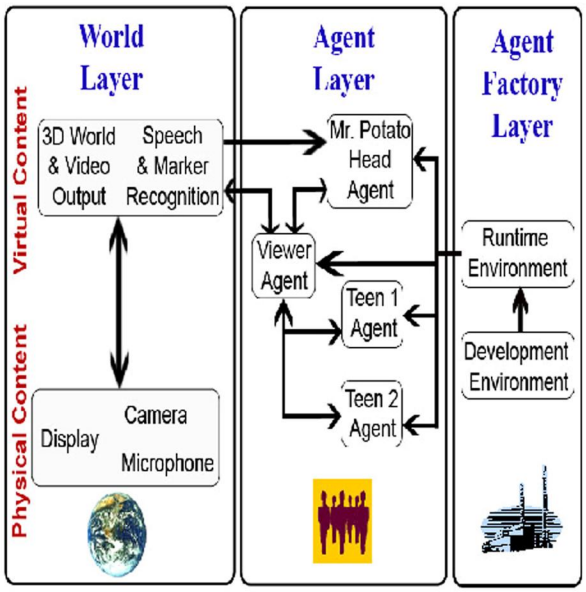

Fig. 1. The NEXUS Framework.

III. Fused Reality Demonstrators

We will now describe briefly two demonstrators which illustrate the use of the NEXUS Framework. Behavioural plausibility is provided through the use of Agent Factory BDI agents. Such agents provide the requisite deductive apparatus for traceable accountable and plausible behaviour patterns. NEXUS avatars thus are far from the shallow containers that typified injected characters often found in previous mixed and virtual reality environments.

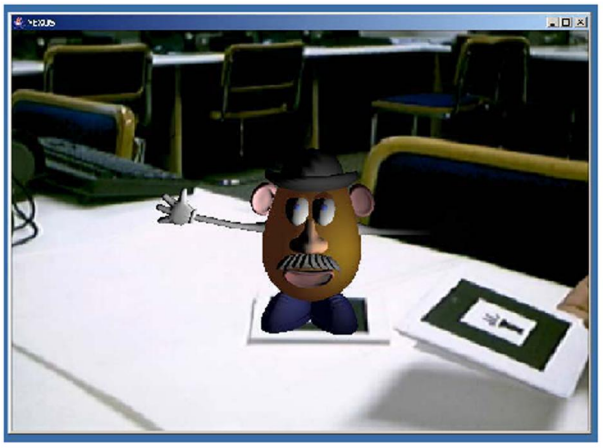

Fig. 2. A "real" flashlight projecting into a virtual space.

The first demonstrator illustrates the NEXUS objective of real and virtual world fusion. Fig. 2 depicts a mixed reality scene in which our hero, MrPotato, is illuminated by a "real" torch. In reality, the light source is merely associated with a torch icon placed upon a card held by a human hand.

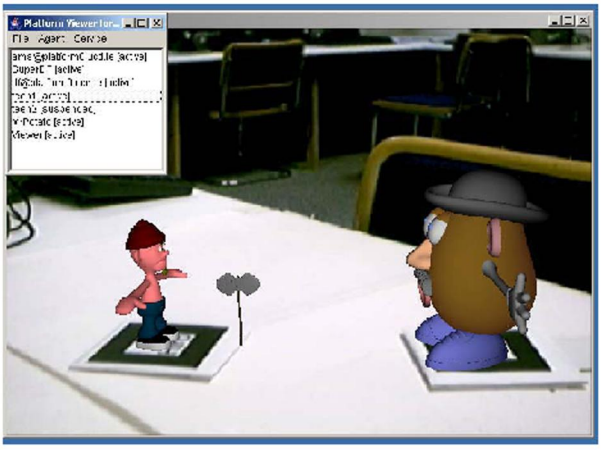

Fig. 3. The augmented reality scenario shows MrPotato throwing an axe at the Teen avatar.

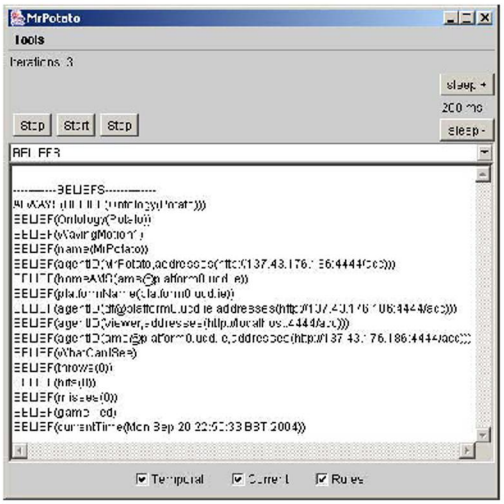

Fig. 4. MrPotato's mental state structured in the form of beliefs about the environments it inhabits.

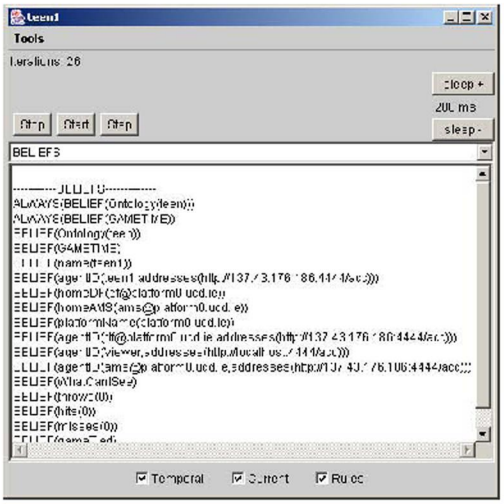

Fig. 5. Teen's corresponding mental state structured in the form of beliefs.

Fig. 3 depicts a multi character mixed reality scene where the two actors namely, MrPotato and Teen, participate in an acrimonious axe-throwing encounter. Close examination of the mental states of MrPotato (fig. 4) and Teen (fig. 5) illustrate their belief states at a given instant in time. Avatar behaviour is driven by commitment adoption which results in future directed actions.

These demonstrators illustrate the integration of deliberative BDI agents into virtual and augmented reality environments which are strongly context dependent. They engage the user in proactive intentional interactions. The *functional* boundaries between the real and virtual are merged into one cohesive functional space.

IV. Discussion

This paper has briefly discussed NEXUS, a layered architecture that supports the rapid construction of mixed reality experiences. It encapsulates BDI agent machinery which may be used to manage autonomous virtual characters together with a collection of visualisation technologies. The rich behavioural realism is achieved through the BDI agent metaphor. Our intelligent avatars exude plausible behaviour in truly mixed reality scenarios.

Machines have intrinsic properties that are often seen as hindrances when the reference is uniquely either the physical world or the virtual. The objective is to embrace those aspects that are constructive and integrate these with the system's inherent advantages, i.e. being an *artificial* system. The primary research goals are the challenges of understanding and establishing a coherent fusion between what have been traditionally viewed as two separate realities, which work on augmented realities has looked to try to bridge. This work extends this with the provision of stronger functional capabilities traversing the reality boundaries.

With the integration of multi-modal realities, more sophisticated concepts such as migration, mutation, and strong artificial evolution propose a new dimension in artificial systems. Experiments have been undertaken that demonstrate these concepts, including survival of the mobile agent (see [2] for details). Such deductive entities reside within embodied containers and exhibit the key attributes of autonomy, mobility, mutation and evolution. Within this work, mutation and evolution are regarded as higher order attributes synonymous with chameleon-like agents in developing a new and more sophisticated *agent class*. A complication arises in the field of explicit social interaction between these systems and people within those nomadic agent environments where the degree of social cohesion is typically weaker. The agent dynamics can produce primarily transient relationships. This is further compounded by the mutation of agent forms, which degrades the visual cues that assist recognition and relationship formation. Work on behavioral continuity and persistent aesthetics is looking to address this.

V. Conclusion

On-going work is both examining the derivation of models of trust reliance and dependence within such nomadic agent communities and, practically implementing the NEXUS framework in the field of business information accessibility. The aim is to facilitate a seamless interaction between real office environments and 3-Dimensional information representations normally exclusively viewed in cyberspace. This aims to extend on such work as viewing architectural and engineering virtual models in augmented reality with the functional of the real and the virtual.

Acknowledgment

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