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Agency, Mobility and Virtuality: A Necessary Synergy

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ABSTRACT

This paper will examine and explore the interplay between the key ingredients of Agency, Mobility and Virtuality. Several distinct themes will be considered. Firstly the presentation will address the issue of mediation of virtual environments through the use of agent based systems. In particular how agents can monitor user interaction and based upon this assemble user profiles that may subsequently be used for the dynamic, opportunistic customisation of the virtual environment.

Secondly it will consider the issue of delivering media content to the mobile citizen, when they need it, where they need it and in a form relevant to their technological context. Finally it will consider the dualities that exist between mobile software artifacts and mobile hardware artifacts. Specifically this will be illustrated through the deployment of systems of social

Keywords: Collaborative Virtual Environments, Multi-Agent Systems (MAS), Virtual Reality Mobile Systems.

1 INTRODUCTION

Within this paper we address three key facets of the multi-faceted stone which constitutes the delivery of adaptive, immersive environments. We contend that these facets are those of Agency, Mobility and Virtuality. This paper will in particular explore the interplay between these pivotal ingredients.

We will seek to achieve such an investigation through reference to several on-going research projects currently active within the PRISM (Practice and Research in Intelligent Systems & Media) Laboratory. In particular we have witnessed a convergence of certain key technologies that have over the last few years proven of great interest to our research. Indeed it has been our research goal of late to effectively mine the emerging synergies.

Within this paper we examine several interesting themes. Firstly we examine mobility and in particular the similarities and contrasts that exist when users/artifacts move within differing spaces. It has long been recognised by the Computer Support for Collaborative Work (CSCW) community that users are distributed across a time dimension in addition to their geographic dispersal.

2 MOBILITY

Mobility can be characterised in many ways. We define mobility to be the ability of a user/artifact to move within a given space. In particular there are two instantiations of mobility that we will consider. Firstly the movement of a user and secondly the movement of artifacts. In the former there are two categories that we will outline the movement of a user within a physical space and the movement of the

1 Virtuality is at present a term that the leading dictionaries do not acknowledge. We operate on the basis of language evolving to meet the needs of expression.
user within a virtual space. However, it is worth noting that whilst moving in a particular space the user may be simultaneously moving through parallel spaces like those of the time or the social dimension to mention but two. In the latter category we examine the movement of robotic entities and software agents.

Interesting analogies exist when users move within physical and virtual environments. When moving in both spaces it is imperative that the system is able to track user movements and general system interactions. Tracking within the physical environment is dependent upon location and orientation technologies. Differing approaches are emerging. The indoor scenario presents the greatest challenges. In the main Infra Red (IR) techniques areChallenging. The indoor scenario presents the greatest challenges. In the main Infra Red (IR) techniques are emerging. The indoor scenario presents the greatest challenges. In the main Infra Red (IR) techniques are used while the outdoor scenario can avail of standard techniques like Global Positioning Systems (GPS). Indeed the 911 directive in the United States obliges mobile telephony operators to be able to locate their devices to within an accuracy of 100 metres, offering base station id as an alternate localisation mechanism.

The HIPS\textsuperscript{2} (Hyper Interaction in Physical Spaces) project in which the author is a participant seeks to offer simultaneous navigation of a hyperspace and an associated physical space. In so doing it seeks to achieve a blurring of the traditional distinction between the physical and the virtual. The user thus experiences a cohabitation of the virtual space and the physical space achieving the ultimate goal of seamless transition from one space to the other. Within the context of HIPS the PRISM laboratory have had primary responsibility for the delivery of an outdoor prototype. The chosen domain was that of the handheld tour guide. The localisation technologies employed have involved the use of GPS augmented with an electronic compass to achieve orientation data. By frequent sampling of these two data sources it is possible to identify the user location and orientation. This tuple combined with the knowledge of the individual user permit the personalisation and contextualisation of the data presented to the user.

Content relevant to the tourist location and orientation is thus delivered to the PDA in a manner relevant to the individual user. A User Model is used to record profiling details for each and every user. Thus even simplistic user models can ensure that content is presented in the users first language and if for example they are a child that the narrative is relevant to their language comprehension. The frequent sampling of the location and orientation inputs enables this course data to be transferred to and assimilated into the user model. When we consider the movement of users within a virtual space then again the need to track the users movement and activity is of paramount importance. A judicious placement of sensors within a virtual world can collate similar data relating to user activity. Worlds constructed within Virtual Reality Modeling Language (VRML) [Vac96], can be populated with a rich set of sensors including proximity, touch and time. The richness of the data collected can often be in excess of that available from sensors contained in the physical space. The only impediment to data collection within the virtual world is the performance degradation accrued through abundant sensor placement. User movement within virtual environments like their physical counterparts embraces the cohabited nature of such spaces. In this context I will draw upon two such research activities those of the ECHOES\textsuperscript{3} (Educational Hypermedia On-line System) Project and that of the ENTER (Environment that Totally Envelopes the useR) [OS+98, GOD00] project. We will however postpone issues of user immersion and virtual environments to the subsequent section.

The second broad category of mobility we wish to consider is that of artifacts roaming an environment. In particular our research has focused upon teams of robots that collectively work together in the solution of shared goals. We have introduced the term social robot and an associated Social Robotic Architecture\textsuperscript{4} both of which have been described extensively in the literature [DG+00, DO+99, OD+99]. We borrow heavily from the Multi-Agent Systems (MAS) arena, considering such robotic entities as being strong agents. We ascribe mentalistic attitudes akin to Belief Desire Intention (BDI) agents [RG91] and incorporate this deliberative layer within a classical subsumption style robotic architecture. Such robots are thus equipped with a rich repertoire of sensory input with which they can sense their environment

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2 HIPS Hyper-Interaction in Physical Spaces (HIPS) Project Number 22574 is funded by the European Commission under the Long Term Research (LTR) DG XIII Intelligent Interfaces Initiative.

3 ECHOES (European Project Number MM1006) is partially funded by the Information Technologies, Telematics Application and Leonardo da Vinci programmes in the framework of Educational Multimedia Task Force.

4 This work has been conducted under Enterprise Ireland grant SP/97/08 IMPACT (Initiative for Mobile Programmable Agent-based Computing Technologies).

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including odometry, bump sensors, sonar and an on
board vision (Figure 1).

Again the world is highly dynamic and is cohabited
robots are mobile and autonomous and are
profoundly social in that they can communicate using
an Agent Communication Language (ACL) Teanga
based upon Speech Act Theory. Such interaction is
supported across a wireless network. In addition to
considering the robots themselves we have also
considered certain software packages as agents.
Particular robotic capabilities may be nomadic in
nature and roam the network converging on those
location(s) where they are most needed [CR+00].
These mobile agents again constitute another

dimension of mobility and offers an interesting
duality between mobile consumers of data and
mobile agents that deliver such content.

3 VIRTUALITY

The main objective of the ECHOES project [PSO99,
OS+00] was to build a distributed dynamic
environment for educating and supporting technicians
in the use and maintenance of complex industrial artefacts. To pursue this objective, Computer-Web
Based Training, Virtual Reality and Multi-Agent
Systems were integrated and synthesised into the
ECHOES environment.

The ECHOES system constitutes a specific instance
of the broad class of system namely Collaborative
Virtual Environments (CVEs). The ECHOES training
environment remotely immerses the engineer or
trainee into a familiar virtual environment and a
virtual community where they can receive
information and assistance, communicate and
virtually meet with colleagues and collaboratively
solve tasks. This environment is delivered via the
internet through VRML where the user presence is
depicted through an avatar which is moved through
the space by way of the External Authoring Interface
(EAI) dynamically updating the .wrl file.

The ECHOES virtual environment is based upon the
familiar physical metaphor and trainees can wander a
spatial environment namely the ECHOES training
environment within which users can enter rooms
appropriate to the assistance they desire. At a
functional level the following rooms are provided;
meeting room, library, training room, simulation
room, first aid room and control room. Various
interaction modalities are supported. Users can
communicate by email, navigate the virtual world,
retrieve and view technical manuals in the library,
participate in a virtual meeting, engage trouble
shooting assistance in the first aid room, undertake
courseware modules in the training room, either in a
classroom context or in trainee moderated individual
training booths.

The ENTER environment addresses a contrasting
arena of electronic commerce. The virtual
environment depicts a retail park with users able to
wander both along shopping malls and enter selected
retail outlets. In this environment crucial shopping
behaviour data can be accrued. This can in turn be
utilised in the manage the user experience. We will
develop this point in Section 4.

Figures 2 and 3 depict the examples of the ECHOES
world. In both the ECHOES and ENTER worlds
users are immersed within the environment and
cohabit it with our users. In this sense ECHOES and
ENTER are no different from other CVE s.
One of the formulative pieces of research conducted in this arena was that of the Distributed Interactive Virtual Environment (DIVE) [Hag96]. This constitutes an internet-based multi-user VR system in which participants navigate a 3D space and see, meet and interact with other users and applications. A participant in a DIVE world is called an actor, and is either a human user or an automated application process. An actor is represented by an avatar, to facilitate the recognition and awareness of ongoing activities. DIVE implements a variety of embodiments. Similar to ECHOES it supports the overlay of photographs onto the face of a selected avatar body. DeepMatrix [RC+98] also supports embodiment through the use of personalisable avatars. Like ENTER and ECHOES it combines VRML and the Java programming language, via the EAI (External Authoring Interface) of VRML. The EAI allows for communication between a VRML world and a Java applet within the same Web page.

4 AGENCY

Much research work has been commissioned on Multi-Agent Systems (MAS) and Distributed Artificial Intelligence (DAI) [OJ96, DLC89, Sho93]. Specifically, competing agent architectures have been proposed in the literature. Two major architectural schools have emerged, namely those of the reactive system school and the deliberative system school.

In the delivery of computationally tractable models of deliberative reasoning, one approach that has gained wide acceptance is to represent the properties of an agent using mental attitudes such as belief, desire, and intention. In this terminology, an agent can be identified as having: a set of beliefs about its environment and about itself; a set of desires which are computational states which it wants to maintain, and a set of intentions which are computational states which the agent is trying to achieve. Multi-agent architectures that are based on these concepts are referred to as BDI-architectures (Belief-Desire-Intention) [Jen93, OJ96, RG91] and have recently been the subject of much theoretical research.

Within all of the systems that we have referred to thus far we have embraced MAS techniques adopted an Agent Oriented Design (AOD) philosophy. All incorporate a strong notion of agenthood. Within our work we utilise Agent Factory in order to assist in their fabrication.

In essence Agent Factory is a tool that facilitates the rapid prototyping of Intelligent Agents. The Agent Factory System has been discussed more completely elsewhere in the literature [OJ96, OCA98, OA95,CR+00]. Agent Factory is a member of the class of systems that embraces the BDI philosophy. The system offers an integrated toolset that supports the developer in the instantiation of generic agent structures that are subsequently utilised by a pre-packaged agent interpreter that delivers the BDI machinery. Other system tools support interface customisation and agent community visualisation. In creating an agent community three system components must be interwoven, those of agents, a world and a scheduler.

The ECHOES architecture is designed using a multi-agent approach. The user interaction with the system is agent mediated and the chosen interface is that of the visit metaphor. An abstract view of the ECHOES Architecture is depicted in Figure 3.3.

The true goal of any CVE is:

- To provide a personalised and contextualised experience;
- To strengthen the notion of the connected virtual community immersing the user into a virtual world together with an associated virtual community.

It is our belief that in order to achieve this one must adopt a multi-agent paradigm. In the context of ECHOES the overall aim of using an agent based system was to enhance user interaction and to provide a customised training environment. The tasks that the agents perform can broadly be divided into...
two distinct areas; firstly customisation of the Virtual Training Space controlled by a User Profile Management Agent, which dynamically responds to user preferences and user actions. Secondly, support for users through CSCW and a First Aid system, whose task is to respond to detailed user queries on complex artefacts.

In achieving personalisation and overall management of the interactive experience it is necessary to put several key ingredients in place.

- A Listener Agent;
- A Profiling Agent;
- A Presentation Agent;

The Listener Agent
The Listener Agent is responsible for gathering information about a particular user behaviour within a given world. This information is used to supplement the static user data solicited at login. It monitors user interaction within a given world by repeated and frequent sampling of sensory inputs. In the virtual world these include proximity, touch and time sensors. In the physical world these involve either GPS, electronic compass and Bluetooth enabled devices, while the robotic case involves odometry, bump, sonar and vision inputs.

Most of the data accumulated by the Listener agent is quantitative in nature. The listener agent traps user events by responding to EAI initiated events. The data captured when the user interacts with the ECHOES and ENTER virtual spaces will typically contain details of navigation paths through the activation of proximity sensors, time spent in different VRML rooms through the activation of time sensors, activities adjudged by the activation of touch sensors.

The Profiling Agent
Initial Profiles are used as the default individual user profile. As such it presents a mechanism for bootstrapping the system personalisation. The profiling agent takes the user information accrued by the listener agent and tries to analyse the data with a view to dynamically augmenting the unique user profile for each individual user. A weighting algorithm is applied to the data in order to extract relevant features which are then used to characterise the users perceived preferences. The user profile represents the addition of added value to the raw user information, transforming quantitative data to qualitative data.
The Presentation Agent
The Presentation Agent is responsible for displaying a desired view of a given world to a given individual. Central to the functionality of the Presentation Agent is its ability to understand the World Description files, which define the position and orientation of VRML components within the world, rather than reverting to a lower level VRML description of the scene. The presentation Agent is then able to manipulate the object types in the world description files using high level pre-defined World Transform functions including inter alia: Swap( ObjX , ObjY ), Move( Obj , Ref ), Rotate(Obj,Axis,Radians). Applying these functions to update the world description file can thus portray scene changes. The judicious choice of when and what transformations to apply is made by the presentation agent through interaction with the listener agent based on user events and the user profile, thus appropriate reconfiguration can be achieved. [GOD00]

Within the ENTER system one of the key thrusts of the research was the ability to dynamically reconfigure the world within which the user is situated. Experience has shown that relatively crude and blunt user descriptors can result in considerable personalisation capacity.

5 CONCLUSIONS
Within this paper we have explored the interplay between three key enabling technologies, mobility, virtuality and agency.

We contend that effective mediation of user interaction can be achieved through the judicious use of agent oriented techniques. A community of intelligent agents collectively monitor user interactions within a given world (virtual or real) and subsequently collates and analyses this extracting features and updating user profiles accordingly. Based upon these profiles tailored information presentation is delivered. At all times the user is blissfully unaware of the very existence of the agent community.

We believe that future systems will need to exhibit two key functionalities. Firstly the ability to opportunistically reconfigure worlds reflecting individual user needs. Secondly the ability to situate the user in various spaces simultaneously supporting seamless movement from one to the other, for example from the physical to the virtual.

In the former user disorientation and inconsistent views may occur. However there is ultimately no reason why the same view needs necessarily to be presented to multiple users even if the co-occupy the same vicinity. Two users located in almost the same position could be presented with starkly differing worldviews. We need merely to ensure that the virtual community view remains consistent in that other users that are within view are perceived by fellow users.

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