I-Room: a Virtual Space for Intelligent Interaction

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Abstract

An I-Room is a virtual environment for purposeful interaction. It is intended to provide support for a range of collaborative activities, especially those that involve deliberation and decision-making. The I-Room acts as a space in which information can be collected, arranged and maintained, and in which participants can collaborate using a variety of communication, presentation and support tools. This concept is founded on a number of complementary principled approaches for guiding purposeful behaviour, which in turn provide a basis for calls to external intelligent systems and knowledge bases. Prototype I-Rooms have been constructed using a popular virtual world platform and used for interactive work and leisure activities; several of these applications are presented here to illustrate the concept.

Keywords: Computer-supported collaborative work; Artificial, augmented, and virtual realities.

Introduction

Barely three-quarters of a century ago, Bertrand Russell felt able to define most human work as "altering the position of matter at or near the earth's surface relatively to other such matter"[1], with collaborating workers necessarily in close physical proximity. In the early years of the twenty-first century, however, this definition looks an increasingly inadequate description of everyday work in the world's advanced economies, work which more and more involves the generation and manipulation of information, and collaboration with others hundreds or even thousands of miles away. There has been a shift from the industrial to the informational mode of production, and high-speed communications networks have globalized the workplace and the consumer market.

Collaboration as Process

During a collaborative informational process, value is added by the application of the knowledge and skills of the collaborators. Information is both the goal of the process and its means, since the collaboration is furthered by the communication of information among the participants. Currently, such work proceeds in a more or less ad hoc manner, conforming to the technological and social constraints imposed by the various tools available for information manipulation and transfer. The starting point of the work reported here is that, just as the introduction of the assembly line to industrial processes increased their productivity many times over, the proper organization of this mode of production can serve to increase the efficiency of the process.

The authors' conception of the information that characterizes collaborative work stems from fundamental research in AI planning and workflow, and the application of this research in so-called *mixed-initiative* (that is, involving humans and

[1] Russell included a second type of work, that which involves telling others to do the first type, noting that this second is generally more pleasant and better-paid than the first.

computers) activities in various fields. This led to the development of the generic <*I-N-C-A*> (Issues-Nodes-Constraints-Annotations) model [1] of shared activity and its accompanying process methodology.

In its simplest terms, an <I-N-C-A> description represents a process at any stage of its life in terms of four types of information:

- *Issues* represent problems or outstanding questions concerning current activities, or recognized opportunities for more productive or efficient action;
- *Nodes* represent activities that are identified as part of the shared process;
- *Constraints* represent spatial or temporal restrictions on activity and on the availability and use of resources;
- *Annotations* capture meta-information about the other categories, such as rationale, provenance and status.

The <I-N-C-A> methodology involves furthering the process in collaboration with the other participants by cyclically addressing these elements: issues are considered and resolved in terms of further activities or additional constraints; node activities are elaborated, performed or delegated, and the ways in which this is done will raise additional issues or place further constraints; constraint spaces are explored using simulation or analysis to pinpoint feasible activity; and all happens in a context continually enriched by annotation. From an informational perspective, this approach can be viewed as one of performing a process by continuously evolving its description using certain specific operators. These operators essentially introduce or manipulate the structured information that constitutes the <I-N-C-A> description as a result of the performance of the activities that constitute the process. It is this structuring of information that provides the basis for collaboration: the <I-N-C-A> elements of the process are intended to be easily communicated and intelligible to both humans and machines, and can be described in terms as formal or informal as the situation demands. To help put this into practice a suite of tools, collectively termed the *I-X* technology [2], provides generic support for the creation and interaction of a system of agents that is able to apply the <I-N-C-A> methodology so as to enact processes.

However, the application of this approach alone cannot *guarantee* a process will be successful; while it is intended to provide a principled approach, the quality of the collaboration will be determined in large part by the quality of the information available to and shared by the participants. This information describes the current state of the world, standard procedures for specific tasks, available options and evaluation of these, and so on, and, clearly, the better this information the more likely the success of the collaboration. Some of this information will exist in externalized forms, some will be brought to the process by the participants, and some will be transformed and expanded through the participants' knowledge and the application of their analytic or synthetic skills. This work takes place in an environment whose potential for providing, manipulating and sharing information in some sense represents the potential for this and similar future collaborations. As a consequence, if we are committed to providing process support, we need to think about nurturing and supporting this 'information potential', by providing both easy access to the information itself where it exists in externalized forms and the proper environment for tapping into the potential where it remains tacit.

Information Spaces

Reflecting on the conventional ways in which humans approach shared tasks, we see that there is a *spatial* component to these information-manipulating operations: people organize the space around them so as to better perform these tasks. We can observe this spatial aspect in, for instance, a brain-storming session in a small office with whiteboards and flip-charts acting as shared cognitive tools to develop ideas; the use of projector-screens to disseminate presentations to an audience; the careful arrangement of project documents in front of participants during meetings; even in the use of filing cabinets to order and store useful papers. This has led us to make the following conjecture: *successful collaborations occur in an information space which offers access to appropriate informational facilities and resources*. In conventional work practices, involving collaboration with physically co-located workmates, this information space will correspond either wholly or in part to zones of the physical workplace, which we manipulate to better suit our needs. In the new world of global collaborations, we must search for – or create – an analogous space. This space we term the *I-Room*.[2]

In this paper, through the use of case studies of several very different applications, we describe how this I-Room concept has been realized using virtual worlds technology. As we shall see, in our use of virtual worlds we are effectively simulating real-world work spaces – offices, meeting rooms, buildings – and the real collaborative tools these contain, since these are the only models we currently possess for the "appropriate informational facilities and resources" integral to the I-Room. It might be argued, and with some justification, that this does not represent the most effective use of this technology, and risks mistaking the inessential (and possibly, where collaboration is concerned, detrimental) physical

[2] The "I" of I-Room stands variously for "information", "intelligent", "interactive" and "integrated".

aspects of these spaces in the real world for features that are somehow integral and necessary for collaboration, and replicating these accidental features in a virtual world. However, this must be weighed against the advantage of this approach, namely that the simulation of identifiable real-world spaces offers instant familiarity to users, most of whom have had little prior experience of virtual worlds. As the technology continues to improve and develop, and as our experience of developing and using I-Rooms expands, we expect to be able to hone these ideas into virtual spaces that are optimized for (different types of) collaboration.

Furthermore, the I-Room idea is not limited to supporting work processes. Another recent and fundamental change in society has been the growth of mass leisure time. This leisure time too is increasingly expended in information-based activities, with the internet offering the ability to share in pursuits with like-minded people all around the world. We suggest that the I-Room concept can enhance these activities for their participants, and below we describe an application devoted to a leisure activity.

A Brief History of Virtual Collaboration

While strongly influenced in recent years by advances in computer game technology, the origins of virtual worlds and their social networking aspects can be traced to research which began in the late 1970s into multi-user persistent spaces, which explored object-sharing and chat for collaborative systems [3]. The addition of object-oriented programming to script or control the objects in the shared space expanded the possibilities; LambdaMOO[3], dating from 1990, is one well-known example of this type of multi-user, object-oriented virtual space. Work in this area has continued, with the environments now being used alongside tele-/video-conferencing and instant messaging with agent presence and status information. A good example is the Collaborative Virtual Workspace[4] originally built by Mitre Corporation between 1994 and 1999, which used a 'buildings and rooms' metaphor for persistent storage of the documents and shared assets used in collaborations. Many video-conference support systems utilize the idea of setting up a virtual workspace 'room' to give context to a particular presentation or meeting. The foundations of the I-Room project, within the context of the wider I-X Research Programme, lie in proposed extensions to this idea to make use of intelligent planning and collaboration aids alongside CVW. These represent just a handful of the proposals to have appeared over the last decade that describe a room for intelligent team-based interaction or a room that could itself act as a knowledge-based asset for a group. Some of these concepts were explored in the Collaborative Advanced Knowledge Technologies in the Grid (CoAKTinG) project [4].

I-Room Collaboration

A collaboration exists whenever at least two agents work together to achieve some agreed goals. Additional agents can be brought in to participate in this collaboration and participants can leave whenever appropriate. In order to sustain and further their collaboration, the participants must have some effective means of communication. The nature of this communication will depend on the nature of the activities currently underway, and also on the participants, their specific contexts and environments – and on the technologies that the participants share. This last is an important point: for any sort of remote collaboration, there must be a sufficient 'technology overlap' between participants to allow them to share information. This may be as commonplace as telephone or e-mail; here, however, we propose the use of virtual worlds as the communication technology, since this also allows us to situate this communication in a richer (virtual) spatial context in which we will construct our I-Rooms. Modern virtual worlds platforms offer voice/text chat and messaging services that are familiar to most of us these days; moreover, they offer facilities for non-verbal gestural communication. Realizing the I-Room concept within a virtual world would give a collaboration an intuitive grounding in a persistent 3D space in which representations of the participants (their *avatars*) appear and the artefacts and resources surrounding the collaboration can be granted a surrogate reality – which, where these items consist of information, might be more meaningful or compelling than their physical manifestations.

The use of virtual worlds provides us with our technical platform; next we must consider the conceptual foundations of the I-Room.

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[3] http://lambdamoo.info

[4] http://cvw.sourceforge.net

Conceptual Foundations of the I-Room

We can tentatively list a number of complementary concepts that will provide the foundations for the collaboration support offered by an I-Room:

- The use of the <I-N-C-A> model to represent the process and its current state and the use of the <I-N-C-A> methodology for furthering the collaboration, including principled communication based on sharing issues, activities/processes, state, event, agents, options, argumentation, rationale, presence information and reports represented using the <I-N-C-A> framework;
- The use of Issue-Based Information System (IBIS) [5] and Questions-Options-Criteria (QOC) methodologies [6] to provide a structured approach for exploring the ramifications of issues, developing possible responses and their argument-based evaluation leading to decision-making. In a sense, these concepts provide one mechanism for enacting iterations of the <I-N-C-A> methodology by resolving issues in terms of activity nodes. Graphical dialogue mapping techniques and tools have previously been shown to be useful for visualizing and recording applications of these methodologies [7], which lays the groundwork for their use in a virtual world.
- The use of the Beliefs-Desires-Intentions (BDI) model of agency for understanding and steering the behaviour of individual (human and automated) agents as participants in a task-achieving whole. The incorporation of these mental attitudes into the <I-N-C-A> model, with beliefs corresponding to constraints and intentions to nodes, and with desires manifest in the decision-making processes, both allows a process-centric account of agent systems and provides an model for implementing and deploying rational intelligent agents within this system [8].
- Shared or overlapping ontologies and associated vocabularies, as the basis for formal and informal communication – and mutual comprehension – among participants. The use of intelligent systems and services during the collaboration will determine the extent to which these ontologies and their use need be formalized and made explicit.

It should be evident that introducing these complex concepts into practical use in an I-Room is not a straightforward task. It requires experimentation with alternative visualization and interaction metaphors, based on an evolving understanding of human perception of and interaction with virtual space. Nonetheless, the concepts listed above have all been used successfully (and together) in the past – during which their human users have effectively developed their own ad hoc information spaces; it is these spaces which we are now trying to realize in a more formal and shared manner as I-Rooms.

Meeting Support and the I-Room

Collaborative effort can be divided into two types (which, in turn, dictate the form(s) of communication involved): synchronous effort, which requires the contemporaneous interaction of two or more participants; and non-synchronous effort, in which the participants act separately to achieve individual sub-goals. An example of synchronous collaboration is a scheduled project meeting; and since such meetings are, relatively speaking, easy to consider in conceptual terms, have a limited temporal extension, have clearly definable objectives, and, as we shall see, lend themselves to the <I-N-C-A> methodology, we have chosen to focus much of our initial effort on providing support for various types of meeting that exist in this space.

A formal meeting (process) occurs in shared time and, by extension, we can also say that it takes place in shared (conceptual) space – that is, the I-Room. The meeting will usually consist of a sequence of conventional sub-activities, for example, a general introduction to the meeting, a review of minutes from the previous meeting in this series, if any, a review of actions placed on participants during previous meetings, discussions of the main topics of the meeting, and closing business. Within this, the various participants play one or more specific roles: meeting chair, secretary, presenter or attendee.

In <I-N-C-A> terms, the activities that comprise the meeting correspond to nodes in the meeting process. The methodology requires executing each of these activities in turn; the result of this is to generate information, in the form of minutes, decisions made, additional activity nodes (actions on participants), and so on. The I-X tools are used to formalize this information as far as possible – for example, the meeting process is formalized into a plan – to control and monitor the progress of the meeting (that is, the execution of the meeting plan), provide links to the details of previous meetings, automatically compose and distribute minutes. The domain-specific content of the meeting – revolving around discussions leading (usually) to decisions – is supported by a variety of information presentation and sharing mechanisms. And considering the meeting as simply one sub-process within a wider programme of activity – as a meeting invariably is – allows a richer body of contextual informational material to be provided and evolved.

Realizing the I-Room

The meeting activities take place within an I-Room; simply put, the I-Room should provide a conceptual space (in this case within a virtual world) amenable to a successful meeting. The examples used to illustrate the I-Room concept in this paper have all been built in the *Second Life*[5] virtual world environment, which provides users with individual avatars, allows the construction of detailed 3D spaces containing objects with programmable behaviour, and provides all the communications channels (over voice, text chat and instant messaging, gesturing) mentioned above, along with facilities to display external media (video, audio, graphics, web-pages), which in this context effectively become additional communication aids. We have chosen to develop virtual spaces that closely resemble the sort of space that, if available, would naturally be chosen to host the meeting in real life. Thus, each I-Room is a virtual 3D space furnished with 'chairs' for the avatars, arranged for 'round-table' discussions or seminar-like presentations as appropriate, and with a variety of meeting aids ('display screens', 'flip-charts' and the like) according to the nature of the meeting in question. We scale these spaces and the objects within relative to the average size of avatars, but always with an awareness of the particular audio and visual characteristics of the software (such as the in-world distance that voice chat carries). In addition, to interact with the technology, we provide additional tools to support the meeting through generating, manipulating and controlling information. These include automated status monitors, to keep track of participants as they come and go, tools to control the display of information within the I-Room, and tools to monitor and help document the progress and content of the meeting. Avatars can also be given virtual items – such as customized personal information displays and 'name tags' to display to others their real identities and affiliations – that help to smooth the progress of the meeting. A special autonomous object in the I-Room (the *I-X Helper*) has been created to communicate information with elements of the I-X tool suite, which run externally to the virtual world, thereby providing access to the process support offered by the underlying <I-N-C-A> methodology, and to offer a route by which knowledge-based support in the shape of third-party intelligent systems can be made available to the I-Room and, hence, to the process.

These initial realizations of the I-Room concept have entailed a significant amount of specialized effort (requiring graphical modelling, HCI and programming skills); this provides the necessary basis for experimentation with our conceptual ideas, our primary concern as Informatics researchers.

Case Studies

Over the last couple of years we have constructed and deployed I-Rooms for a range of meetings, as well as other collaborations such as training exercises, and always with the participation of real prospective end-users keen to see whether the technology can support their processes. This section describes several applications, all created in Second Life, to support meetings in a creative industry (the development of a multi-media video games); to support virtual operations centres for emergency response and public safety; and to support a social/educational activity (an expert-led whisky-tasting). Without delving too deeply into the technicalities, these case studies are intended to give a flavour of the sort of collaborations that are currently being supported by I-Room technology, and some indication of the directions in which future work will take these ideas.

Slam Games I-Room – Support for Product Team Meetings

Slam Games Ltd. is typical of companies operating in the modern creative industries, with a strong emphasis on information creation and exchange for, in this case, the development of video games. Working in partnership with Slam Games, an I-Room has been created to assist the company's game development process, which involves an international team of designers, artists and managers. For game development, Slam Games itself concentrates on the design, programming and development of the game core, while the design and production of most artwork, sound and other media are outsourced to specialists, who may be located anywhere the world. Hitherto, communication with these media artists has been maintained via a variety of channels (e-mail, telephone, instant messaging, a wiki, and an issue-tracking system), none of which has proven wholly adequate for supporting the sort of synchronous multi-way interaction that is required from time-to-time during development.

The I-Room developed to address these communication failings has mechanisms for displaying artwork and for showing animations, as well as supporting the flow of meetings and recording argumentation, communications, and decisions. This allows, for instance, artwork in the form of 2D stills from 3D models to be presented by the artist and then discussed by all present (Figure 1). A meeting is seen as one in a wider sequence during which the artwork is successively developed and refined in response to criticism and other feedback from the client; this allows actions from previous

[5] Linden Labs Second Life™ (http://secondlife.com)

meetings to be maintained, discussed and carried forward, with outcomes noted as appropriate, placing the meeting in the wider context of the project with its global milestones, deadlines and deliverables. In this manner, the I-Room provides means by which the various stakeholders can view and contrast artwork in a shared setting that also provides a persistent 'memory' of previous meetings and the current state of the collaboration. Employees of Slam Games advised during the development of this I-Room and participated in trial meetings based around the design of a real game and its related media. These trials allowed a basic qualitative evaluation which confirmed the potential of the I-Room technology in the context of Slam's requirements and the shortcomings of existing collaboration mechanisms.

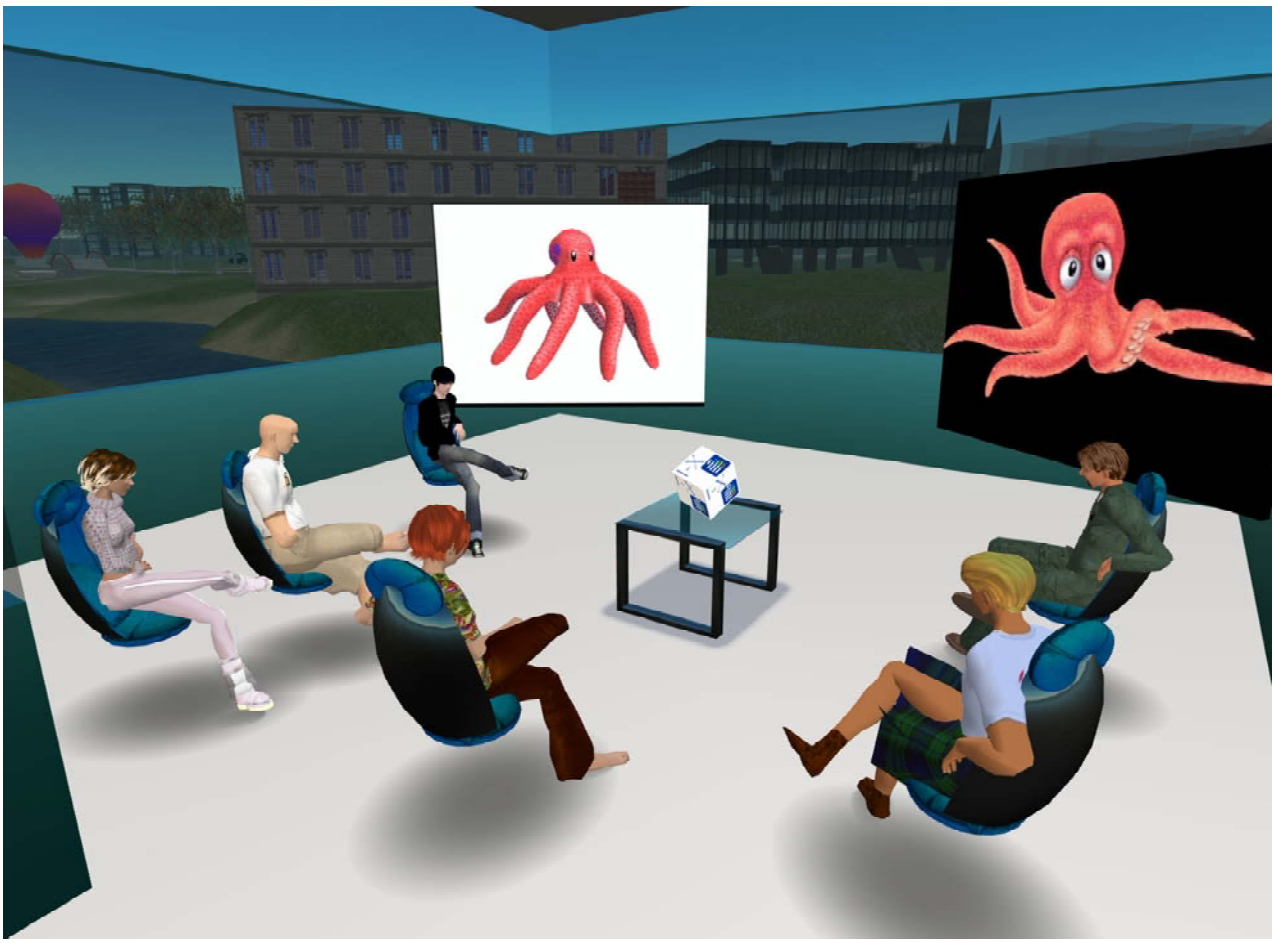

Figure 1. Discussing character design in the Slam Games I-Room.

Virtual Operations Centres for Emergency Response and Crisis Management

An initial spur to the development of virtual I-Room technology arose from research into building the *Helpful Environment* [9], and more specifically from the use of online collaborative planning and task-support systems for search and rescue teams and emergency response. One focus of this work has been to demonstrate the I-Room concept to the Multinational Planning Augmentation Team (MPAT), an organization consisting of 31 Pacific Rim nations whose purpose is to assist in coordinating more effective responses to regional crises such as the 2004 Asian Tsunami; as might be expected, effective communication and information-sharing are essential for coordinating an effective response. Based on discussions with the MPAT Secretariat, along with analyses of their processes and the information that surrounds these, we have developed a prototype Virtual Operations Centre (VOC) I-Room for MPAT-type operations [10].

This VOC I-Room found a role in the Public at Large Scale Events (PuLSE) Technology Demonstration programme developed and promoted by EADS. EADS is a multinational company at the forefront of the aerospace, defence and related service industries; its Innovation Works (IW) UK arm began developing the PuLSE programme in early 2008, with an initial demonstration scenario centred around the task of protecting the public from a terrorist threat to a high-profile sports event being held at the Celtic Manor Resort in South Wales, a location chosen for its proximity to the headquarters of EADS IW UK and because it is to be the venue of the 2010 Ryder Cup golf competition, and as such is currently the focus of real security and safety preparations.

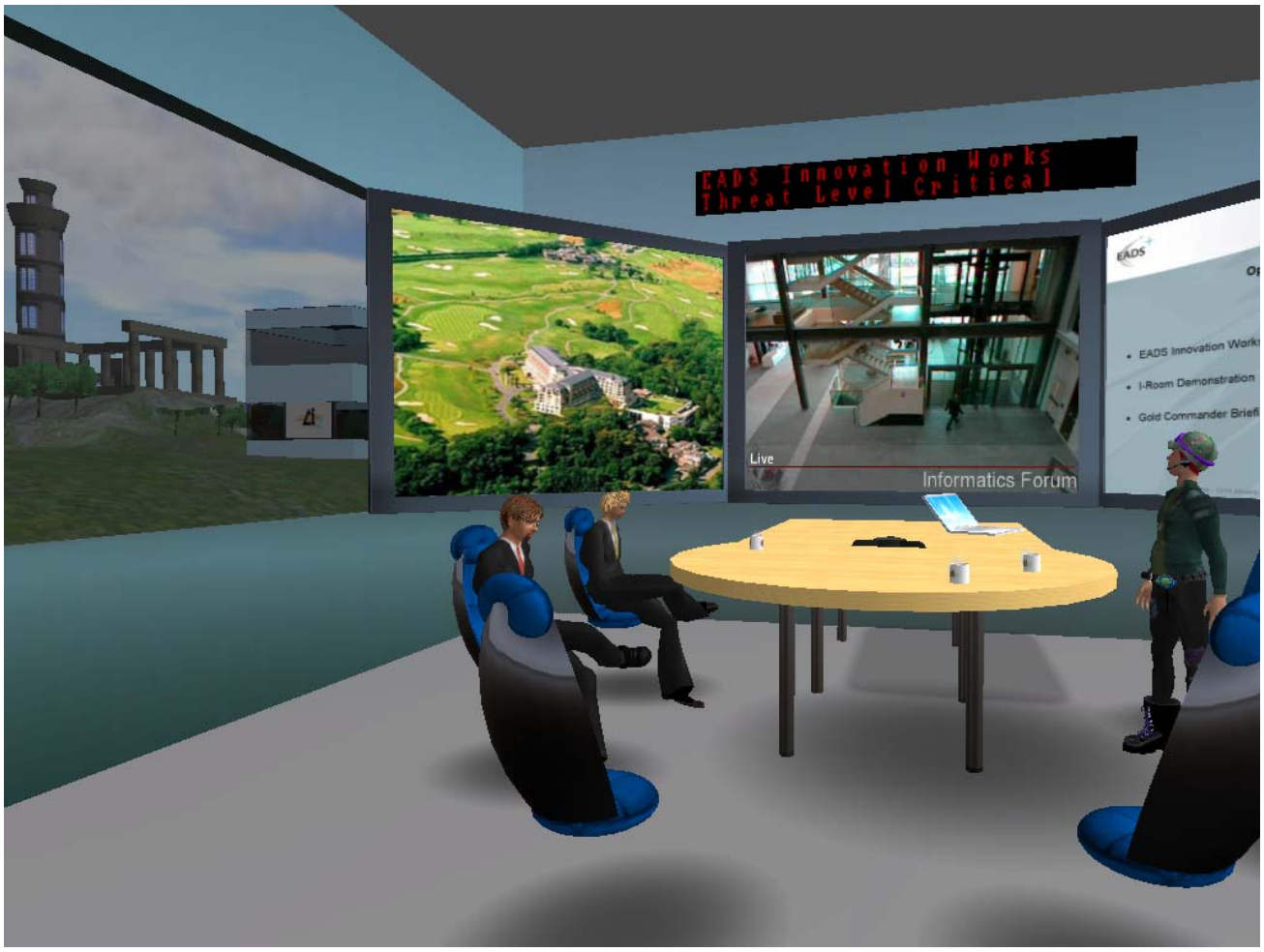

Figure 2. Inside the crisis response Virtual Operations Centre I-Room.

A novel aspect of this scenario was the need for colleagues to interact in both real and virtual spaces. This, and the importance in such situations of providing an audit trail for post-incident review, led to the deployment of a customized VOC (Figure 2) mirrored by a real-world briefing room which, in addition to standard communications facilities, was fitted-out as an *Instrumented Meeting Room* (IMR) that allows audio, video and other feeds to be captured, tagged and timestamped[6]. The scenario, as it was played out, involved the local chief of security, located in the IMR briefing room, developing a plan of action (represented in <I-N-C-A> terms) with his immediate local staff, and then 'uploading' this plan into the VOC I-Room. A virtual meeting was convened with representatives of national government and security services, who were first briefed about the threat and the response plan and, after recommending modifications, were then able to endorse the final plan.

Virtual World of Whisky I-Room

Glenkeir Whiskies Ltd. is a company dedicated to the promotion and sale of Scotch whisky to customers all around the world. Attracted by the social and commercial prospects offered by virtual worlds in the wake of a successful e-commerce venture, it proposed the development of a virtual whisky-tasting I-Room for hosting educational/social events, with an eye to commercial opportunities (Figure 3).

A whisky tasting was held in the Virtual World of Whisky (VWoW) I-Room on January 25th, 2008, to coincide with the traditional Scottish celebration of Burns Night. Supplied with real whisky in advance – there are limitations to virtual world technology! – the participants were led step-by-step through the tasting by a whisky expert. The tutorial itself was represented as an <I-N-C-A> process, with the I-X tools providing process support, which here included access to natural language generation facilities that drew upon an existing knowledge base of Scotch whiskies and distilleries to

[6] See http://www.amiproject.org/

complement the tutor's presentation with factual information. The success of this event – and the enjoyment it provided – has gone some way to convincing those involved of the potential of intelligent virtual world spaces for engaging with social users (and potential customers).

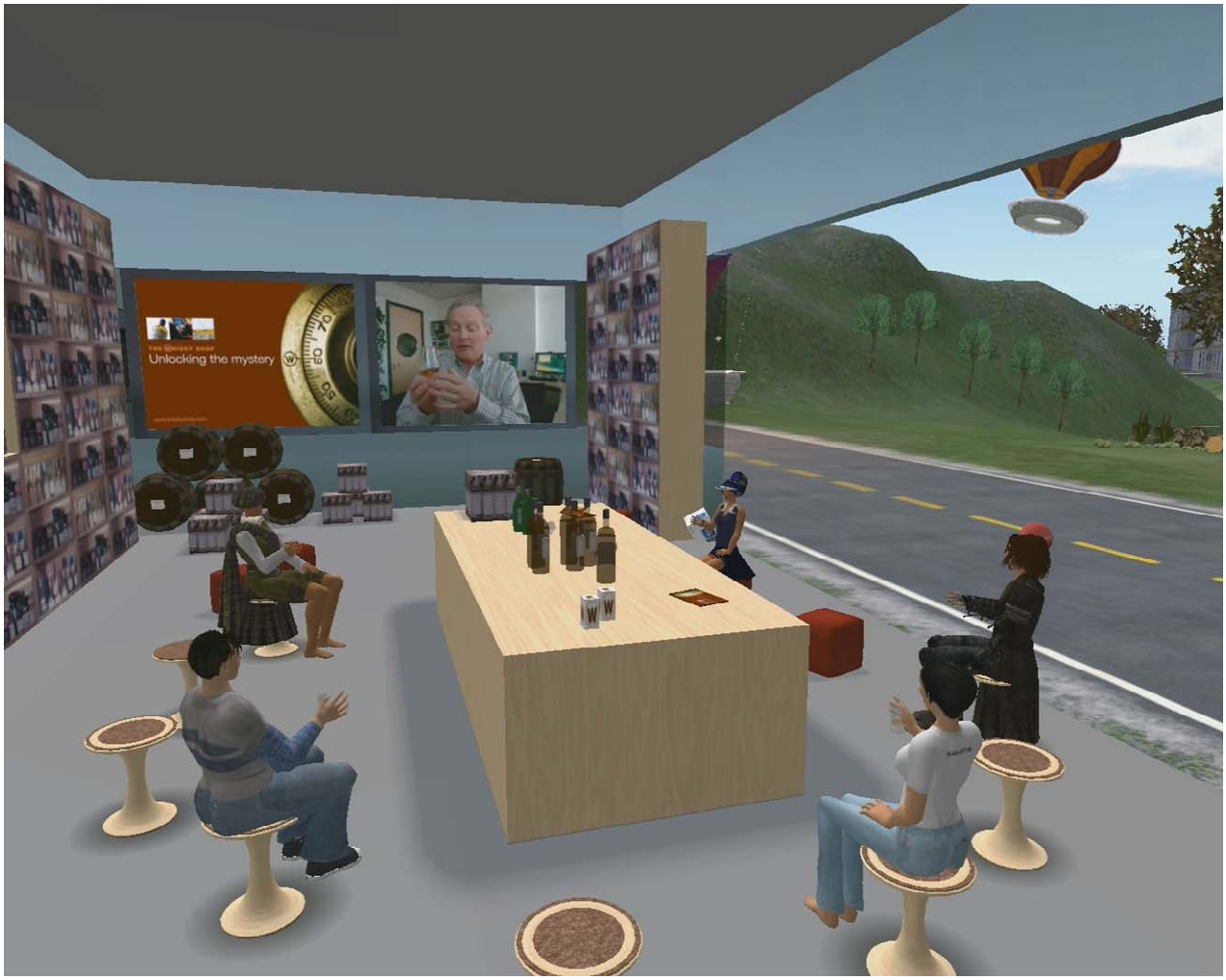

Figure 3. Enjoying a tutored virtual whisky tasting in the Virtual World of Whisky I-Room.

What Does It Mean?

The I-Room concept is intended to support rich process-driven interactions between participants located at physically remote locations. This is a new way of working, and as yet we lack detailed theories of how such collaborations proceed and, indeed, succeed. The approach we have taken so far is a pragmatic one: we have developed trial I-Rooms for different applications, some more successful than others, and have used these to further our own understanding of collaborative processes and, in particular, the effects of introducing virtual spaces into these processes. It is worthwhile reflecting a little here on the implications of the virtual workplace.

Humans are inveterate constructors of meaning, categorizing and organizing their perceptions of the world around them according to their own purposes. An I-Room introduces a number of artificial elements into this world, taking for granted that its users are able to grasp intuitively the use of a simulated 3D environment projected on a 2D plane (their computer screens), populated by (among other animate objects) avatars of fellow humans, and furnished with information-providing and -managing objects, some recognizably corresponding to real objects, others having no counterparts in external reality. The popularity of video games suggests that people are able to understand – assuming certain conventions are observed – computer-generated worlds, and achieve specific objectives defined in terms of those worlds. These conventions are difficult to pin down, but seem to involve some degree of persistence and continuity of form and behaviour in the virtual spaces, objects and avatars, drawing on intuitive mathematical concepts (covering quantity, trigonometry, change), some conformance with the laws of physics, and a strict conformance with certain cognitive perceptual expectations (manifest in the use of perspective on a predominantly horizontal visual field).

Leaving to one side its social uses, with informational work processes in the I-Room we remain concerned ultimately with achieving things in the real world, that is, with producing artefacts or effecting changes to our environment and circumstances. Hence the virtual process must necessarily and carefully preserve certain relationships to the real world, and moreover, these relationships must be clearly understood by all collaborators. The visual familiarity of the I-Rooms implemented thus far seems to help establish and maintain this understanding, but equally it could be argued that these do not yet exploit the full potential of virtual worlds. As we move towards visual representations of information – research underway involves the visualization of abstract elements of QOC as virtual objects for interactive decision-making, for example – we need to find ways to maintain the essential links with reality, and ensure that the processes and their implications are understood by all participants. A principled basis for doing this is not immediately apparent; builders of computer systems generally rely on the use of symbols that are assumed to exist in the ontologies of their users, ontologies which are appropriately grounded in reality. Here, though, we want to introduce new symbols to represent existing – and perhaps even wholly new – concepts.

Who Are You? Who Am I?

Another area of meaning where confusion might be caused by the use of virtual collaboration spaces is in our understanding of the identities of our collaborators. Typically the user of a virtual world will not be constrained to choose an avatar of the same name, race, social class, age, appearance or sex, and indeed, some or all of these categories may be changed at any time at the whim of the user. To the social user of virtual worlds this is one of their appeals, since he is free to experience social interactions free of any prejudices that accompany his real self. However, for work purposes this presents something of a problem. While the elimination of unfair discrimination from the workplace would seem a positive side-effect, this blurring of identity brings with it questions of trust and authority. These concepts are intimately bound up with questions of identity and the consistency of behaviour. And this fluidity of identity also makes impersonation easier – how can we be sure that the person behind this avatar is who he or she purports to be?

But this confusion does not lie only in a user's relationship with others: her relationship with her own avatar can be similarly perplexing. Activity in a virtual space gives users a certain amount of latitude to behave differently from how they would in analogous real-world situations. While once again this ultimately might prove a strength of virtual collaborations, with users less inhibited than would be the case in the equivalent real-world situations, in practice it is necessary to observe certain behavioural protocols in order to follow the methodologies we propose. Current work is investigating the content and form that such protocols should adopt. But it is not just protocols that govern behaviour. People modify their conduct – not to mention their dress and, to some degree, their appearance – according to the environments in which they find themselves. The I-Room must set the right tone for the activity it will contain: we want people to behave *as if the I-Room were real*.

Summary

The internet is changing at a fundamental level both our work and leisure activities, allowing interactions that would not previously have been possible, with information replacing matter as the raw material and the object of these processes. Supporting these processes, and helping to maximize their potential, involves creating and maintaining the information space that surrounds and defines them. An I-Room is a shared persistent space, founded on process methodologies, and offering intelligent systems support for interaction and collaboration between users, systems and agents. The I-Room case studies described in this paper all employ virtual worlds technology to provide this interaction space, and show how this can be augmented with external knowledge-based and intelligent systems.

We have adopted a (perhaps necessary) pragmatic approach in developing the I-Room concept: armed with some basic conjectures, we construct prototype rooms and throw them open to users, watching what happens and hoping to gain a better understanding. From the perspective of the Informatics researcher, the I-Room concept, in common with many areas of human-computer interaction, presents problems of critical evaluation and assessment of the methods adopted. Since it opens up possibilities for new ways of collaborating, there is no convenient benchmark of existing behaviour against which it can be measured. As mentioned above, the goal of collaborative process is to add value to the process and its results: time-and-motion studies of the process and the value of the product (assuming the product has a commodity value that can be realized in monetary terms) could provide quantitative evaluation. As we have seen, however, there are plenty of collaborations that do not produce such commodities, and as such we must resort to qualitative measures and subjective opinion. This remains a difficult question.

Notwithstanding the difficulties of applied research in this area, the results of our initial experiments are promising enough to encourage further work. We are continuing to develop I-Rooms for a variety of applications, and in parallel our research is leading us to experiment in areas such as virtual representation of process and issue-based argumentation,

automated tutoring systems and semantic tagging of content, as well as the more fundamental – and, as we see it, necessary – tasks of deploying process support methodologies for virtual collaboration.

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