Interactive Space Generation through Play

Exploring the Role of Simulation on the Design Table

Ava Fatah gen. Schieck[1], Alan Penn[1], Chiron Mottram[1], Andreas Strothmann[2], Jan Ohlenburg[3], Wolfgang Broll[3], Francis Aish[4], Simon Attfield [5].
[1]The Bartlett, University College London, [2]Linie4 Architekten, [3]Fraunhofer FIT, [4]Foster and Partners, London, [5] University College London Interaction Centre (UCLIC).
ava.fatah@ucl.ac.uk

Abstract

In this paper we report on recent developments in the use of simulation as an aspect of design decision support for architecture and planning. This research is based on ARTHUR (Augmented Round Table for Architecture and Urban Planning). Although real time simulation has been incorporated in design support systems, little attention has been given to the simulation of pedestrian movement in collaborative AR based systems. Here we report on user evaluation tests of the ARTHUR system, which are focused on the effect of real time pedestrian simulation on the way pairs of designers work together.

These tests suggest that the integration of simulated pedestrian movement on the design table plays a critical role in exploring possible design solutions and encourages different and new ways of thinking about design problems. Donald Schon's concept of the reflection-in-action provide a useful framework for interpreting these results.

1. INTRODUCTION

The use of computers in design can be traced over at least three decades. Developments in user interfaces have evolved from the early command line interfaces, where geometry was usually created and manipulated by typing commands, towards the current user interfaces with the ability to manipulate graphical representations of objects on the screen with the mouse interactively through direct manipulation. One of the earliest examples of an application using direct manipulation operations is *Sketchpad* by Ivan Sutherland. This was the first GUI (Graphical User Interface), long before the term was coined. However, for a number of reasons many earlier expectations that computers might fundamentally change the ways we design did not come to realization and the common perception of the application of CAD (computer Aided Design) to architectural design is still associated with drafting and modelling [1].

Developments in computing for architectural design since the 90s follow a number of main lines: VR (Virtual Reality) represents one development, which for a number of reasons, including cost and the unfeasibility of working in a completely immersive environment, continued to be of an academic rather than practical interest. In the last decade a new research wave has emerged linking the digital and the physical worlds. This has led to the identification of a number of key research areas; one of these is AR (Augmented Reality) with its capability of augmenting the physical world with digital information. Additionally, a number of tangible user interfaces were introduced as an attempt to explore the relation between the digital information and the physical representation [2]. It appears that the use of the computer in architectural design is currently facing the challenge of getting past the WIMP user interface (Window, Icon, Menu, Pointing devices) introducing new techniques that take advantage of the capabilities of today's computing systems and match human capabilities more effectively. AR spatial interaction techniques form one possible candidate for the post-WIMP interface that may help change the current approach in the design process. Moreover, and in order to achieve this, CAD needs to support the critical dialogue between design ideas and their expressions. This was recognized by Donald Schon [3], who proposed a theory of reflection-in-action acting as a framework for design learning and teaching based on his analysis of the design dialogue between an architecture student and a studio master. One way of realising this is by integrating simulation techniques such as pedestrian movement analysis into the design process, which could be seen as the binding link in the dialogue while going through a cycle of reflection-in-action. This was supported by our observations of designers collaborating while interacting with a pedestrian movement simulation within the ARTHUR environment, which suggests that the new AR medium seems to hold out a prospect for quite different ways of working leading to new forms of collaboration.

In this paper we present recent developments in ARTHUR, our approach to an AR system supporting collaborative architectural design and urban planning. First past and current related work will be reviewed. Next we give an overview of the system. We have previously illustrated elsewhere early results of the user evaluation of this system [4]. Here we describe preliminary feedback related to the early stage of CAD integration and we report in detail on findings of recent tests with the pedestrian movement simulation on the design table.

2. RELATED WORK

Over the past few years there have been several attempts to apply AR systems in the area of architectural design and urban planning. One of the early examples provided users with an *X-ray vision* inside a building, by visualizing the hidden elements of a building [5], [6]. Other AR systems supported the assembly of complex systems, for instance, *Augmented Reality for Construction* [7], for the construction of space frames by indicating the position of each structural element in space. Dias et al [8] developed *MIXDesign*, a Mixed-Reality system oriented towards architectural design, limited to basic manipulation of imported geometry and using tangible interfaces with AR Toolkit patterns [9] and paddle gestures.

An approach that goes beyond the visualization of spatial designs is the support of collaborative design. More recent AR systems provide common view and collaborative manipulation of complex spatial compositions such as *BenchWorks* [10]; *Magic Meeting* [11]; *ARVIKA* [12]; *AR Planning Tool* [13];*Tiles* [14] and *BUILD-IT* [15]. These systems are described in more detail in [4]. An approach that goes beyond this is the support of collaborative architectural design and urban planning meetings through 3-dimensional computational simulation. This approach is applied in a number of current and recent research projects:

URP [16] is an early prototype for collaborative urban planning. The infrastructure allows digitally augmented tagged physical models placed on a projected table surface to cast shadows accurate for any time of day, and to throw reflections off glass facade surfaces and visualise a simple 2D CFD (Computational Fluid Dynamics) analysis of wind flow.

The *Luminous Table* [17] developed by the Tangible Media Group integrates sketches, physical models, and computational simulations into a single workspace. Physical objects are tracked with cameras. 2D drawings and 3D physical models are augmented with a 2D video projection to simulate sunlight shadows, wind patterns and traffic.

Illuminating Clay [18] supports real-time computational analysis of landscape models. Users change the topography of a physical clay model while the changing geometry is captured in real-time by a ceiling-mounted laser scanner. The results of the analysis are projected back into the workspace and registered with the surfaces of the model.

Digital Sandbox [19] is a single user system that provides designers with the ability to manipulate a digital landscape using hand gestures. It uses image processing of hand gestures from two video cameras to infer the landform sculpting actions and simulates storm water accumulation over the digital terrain. The interaction and the simulations are projected on a vertical projection screen.

MouseHaus Table [20] is a physical interface for urban pedestrian movement simulation in a group setting. The portable interface includes a video camera, colored paper, scissors, and a table with a projected display. The physical interface is driven by an image processing program to capture and analyze the images. With a registration process, users can employ color paper cutouts to represent building type, size, and location as input for the pedestrian movement simulation program.

Create [21] developed a mixed reality framework enabling real-time construction and manipulation of virtual objects using immersive stereo displays and a wide projection screen (CAVE-like environment). The aim is to provide the user with interaction within highly realistic environments including real time vehicle and crowd simulation.

AR systems for collaborative design and planning typically support the spatial composition of larger designs from existing building blocks (compare BUILD-IT and Tiles). They integrate planning rules (compare AR Planning Tool) and sophisticated interaction metaphors (compare MagicMeeting and Tiles) and they have mature concepts for integrating physical and digital workspaces (compare Luminous Table and ARVIKA). However, they are restricted regarding intuitive interaction mechanisms and functionality. Typically, AR planning systems are limited to basic manipulation of imported geometry. Our approach : ARTHUR supports complex architectural design and planning decisions with an attempt to preserve natural communication and collaboration between meeting participants using optical see-through augmentation and wireless computer-vision based trackers to allow for a natural 3D collaboration. Moreover ARTHUR integrates a CAD system to support more advanced functionality such as 3D sketching and extrusion. Geometry is not just imported from modelling software, but can be directly created within ARTHUR [22]. Furthermore, the ability to subject a design to a simulation of functional performance is a critical component in the development of the ARTHUR system for the round table collaborative design. In order to simulate realistic movement patterns and rates we have developed agent simulations in which an agent’s forward facing field of view is sampled, and an immediate next step chosen from that field. In this we have relied on previous research that has found that visual field based movement of this sort provides a good correlate with observed aggregate movement behaviour in urban environments and buildings [23], [24]. In the following sections we present our approach: ARTHUR. It integrates form creation with the simulation of pedestrian movement, as an important component of the collaborative design table. ARTHUR uses optical augmentation and wireless computer-vision (CV) based trackers to support collaboration within the 3D environment. Computer Vision techniques take input from stereo Head-Mounted Cameras (HMCs) and a fixed camera, to track the movements of placeholders on the table, the 3D pointer and the user's hand gestures. Virtual objects are displayed using stereoscopic visualization to seamlessly integrate them into the physical environment (Figure 1).

Figure 1: Collaboration within the ARTHUR environment

3. SYSTEM OVERVIEW

The ARTHUR system is an (AR) Augmented Reality based environment to support the collaboration of architects and other users at architectural design, urban planning and review sessions. It uses AR to project virtual objects on top of a real round table by enhancing the real meeting situation with live 3D information. In the following we give a short overview of the ARTHUR system. The individual system components are described in detail in [4].

The ARTHUR system consists of four main components:

1. The HMDs (head-mounted displays) provide a high-resolution image of the (3D) virtual objects, superimposing the real environment of the user using an optical see-through mechanism. Thus in contrast to VR (Virtual Reality) displays, the user is always part of his or her natural environment, fully aware of any real events (Figure 2) Left".

2. The user interface mechanisms described are realized using computer vision (CV) techniques. Cameras mounted on the HMDs or above the round table recognize movements of placeholder items or wands and recognize user gestures (Figure 2).

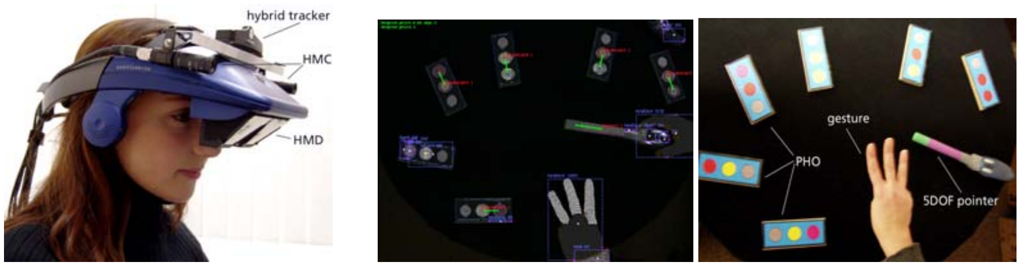

Figure 2: Left: ARTHUR See-through HMD and CV-based recognition of PHOs, pointers, and finger gestures.

3. An AR framework supports the connection and communication of all these devices and links them to the actual architectural design, urban planning and simulation applications by an application interface. The framework supports multiple users, ensuring that all participating users see identical virtual objects on the table.
4. A graphical user interface definition environment (GRAIL) allowing experienced users to configure and adapt the user interface of the AR environment. Thus the users may specify how to manipulate (for instance scale, move or restructure) virtual objects using the interaction facilities provided. The relationship between particular input mechanism and actions can easily be configured using a simple and intuitive 2D drag and drop schema. This interface also allows for the connection to other applications such as the pedestrian simulation (Figure 3.Left).
5. The ARTHUR system has integrated a major CAD system (MicroStation) enabling architects and engineers to directly create and manipulate a virtual (CAD) model during design and review sessions. The virtual model is displayed on top of the Augmented Round Table using the head mounted displays. By using a 3D pointer or finger gestures, the users are able to draw directly in the (augmented) real world, without having to use a separate CAD workstation. Virtual menus floating above the Augmented Round Table allow CAD tools to be selected, e.g. drawing b-spline curves, spheres and tori, as well as extruding surfaces and changing colors. After selecting a tool users are able to draw the appropriate objects in 3D space. Additionally, the users are able to move

and delete objects. The virtual menus are bound to placeholder objects (Figure 3. Right) and therefore can be moved around on the table to get them into the view or move them out of the view to enlarge the working space. The system architecture will allow all tools and functionality of the CAD software to be integrated into the ARTHUR system, e.g. solid modelling, constraint solving, etc. As such, ‘full fidelity’ CAD models are created and interactively displayed by the system; there are no translation or conversion issues and the CAD models can be used directly in downstream design processes [22].

Figure 3. Left: Linking the agent software in GRAIL. Right: Interaction with CAD menus in ARTHUR.

4. USER EVALUATION TESTS

User tests were carried out on a regular basis throughout the ARTHUR project. Beginning with simple scenarios involving only limited interaction, test scenes were gradually enhanced to become more sophisticated and more reflective of architectural design and collaboration.

We have reported elsewhere on the formal user tests and the preliminary usability evaluation performed by the application partners as part of the early prototyping development [4].

Here we report on early findings related to the evaluation of the system as part of the ARTHUR public demonstration at the Fair for Information Technology and Telecommunications (CeBIT 2004) in Hanover. We then review findings from the system in use with simulated pedestrian movement on the design table, including qualitative feedback before finally discussing issues related to the integration with CAD.

4.1. Evaluation of ARTHUR at “CeBIT2004”

In the Public demonstration at” CeBIT 2004” a large number of people participated in either a single user or in a multi-user environment depending on their preference.

These users were all first time users with no previous knowledge of the system. The interaction techniques consisted of simple object creation and manipulations using simple geometric transforms (translation, rotation, scaling). Placeholder objects and pointers were used to interact with virtual menus or to select, move and manipulate the shape of virtual objects e.g. a church.

A brief description of the system and instructions were given by a demonstrator, and then the participants were invited to use the system (Figure 4).

Figure 4: System set-up at "CeBIT 2004".

All participants were observed, and notes were made of the difficulties they experienced and assumptions they made about the user interactions within the system. Of these subjects, ten who showed particular interest in the system were asked to provide detailed feedback in a form of a questionnaire.

The church scenario was presented to a wide audience at CeBIT 2004 –an ideal testing ground with a broad scope of unbiased subjects. The task is to re-create an example 3D church model already placed within the scene. The scenario includes not only design evaluation tasks but also real form creation of simple geometries. It confronts the user with an urban context model with a free site in the middle. A 3D Pointer, PHOs and gesture input are used to create and manipulate boxes, spheres, cylinders, and cones. The Pointer is used as a selection and manipulation device for objects as well as a selection device for 3D menus (Figure 5. Left). The PHOs are connected to the two 3D menus in the scene as well as the example building. They are used to move and rotate these objects on the table plane (Figure 5. Right).

Figure 5. Left: Interaction with the 3D pointer. Right: Interaction with PHO.

Results

For technical reasons, gesture input was seldom tested. Users mainly interacted with the 3D pointer and the PHOs (Figure 6). Generally, it appeared difficult to understand the virtual objects as integrated in the physical environment. This might be expected since physical laws e.g. gravity and inertia, are not applied. It was not easy to understand distances, and subjects, especially those with CAD experience, pointed out that a common view of a situation might help collaboration. This appears to be partly a result of the restrictions on a user’s movement in their environment imposed by the system, the weight of the HMD and its cables, and the need to keep the PHOs that sit on the table in the field of view in order to allow head tracking. Ideally, users should be able to move their heads freely and wander around the table. In addition, the appearance of the virtual objects as always superimposed on real objects, especially the user’s hands, may have led to a loss of the feeling of the virtual as existing within the real world. In conclusion, users found that the properties of the interaction space, viewed through a relatively narrow field of view provided by the headset, are currently closer to those of an immersive VR than an augmented real space [4].

Figure 6. Left: Interactions using the 3D pointer. Right: Using the PHO and the 3D pointer.

Having said that, we observed that PHOs were easily used by all participants. Robust tracking and the *hands-on* quality ensured immediate use for moving and rotating 3D menus. Using the Pointer, however, revealed substantial differences between users. Although most users were quick to embrace the Pointer interaction to them, prior experience with MR-systems (Mixed Reality) as well as in part the *generation gap* seemed to be of substantial importance. People with prior experience were quick to comprehend the scene and interact with it easily. The same was true of several youths who gave the system a try. Acquainted with today's computer and video games, they seemed to have no problems moving on to the *next level* of HCI (Human Computer Interaction). These users compensated easily for one of the major drawbacks in the current system setup that became obvious at CeBIT. Since a major part of object tracking is achieved using HMCs (Head Mounted Cameras) , users had to be cautious to keep the 3D pointer in the field of view of the HMCs at all times when interacting with the scene. The problem is one of perception. The tracking system sees the pointer as an object with one element: the coloured markers attached to the front end. The user, however, sees two components. For one, there is physical device itself (the user does not distinguish between the actual handle and the markers – it is one device). Secondly, there is the virtual selection beam emitted from the front end of the pointer. The user's point of orientation, however, is not the physical device but the virtual beam. A parallel seems to be the handling of a sword. A swordsman does not have to see the shaft of his sword – he keeps the blade in view instead.

Although testing time was limited for each individual, multi-user interaction was permanently sparked by the situation of sitting opposite one another and obviously manipulating the same scene. Users would exchange the virtual menus by pushing the PHOs towards the other user. Also, they would at times try to manipulate an object created by another user. It should be noted, however, that the latter seldom took place when the person who originally created the object was still present. Users seemed to view objects created by a particular user as, in a sense, belonging to that user.

All in all, the CeBIT test runs were highly successful. They provided not only valuable feedback on shortcomings, more importantly they verified the approach and the direction taken in developing ARTHUR. Most users quickly got into using the system and were then happy and willing to play with it and - on several occasions – test its limits (many users managed to scale the church to several times its original size and seemed to enjoy the resulting dwarfing of the cityscape) (Figure 7).

Figure 7 . Left: Moving the church. Right: Scaling the church.

Figure 8 summarises factors affecting interaction and interrelationships between aspects of interaction, comprehension (of the space) and collaboration. Starting from top-left of the figure, properties of the HMD and HMC are shown leading to restricted movement and visibility. Although, some adaptation was seen dependent upon age and experience with similar technologies. Restrictions on visibility, in turn, resulted in reduced comprehension of distance, and, in combination with reversed occlusion and the lack of gravity or inertia, reduced integration of the virtual and real spaces. The restricted visibility also led to the suggested need for a shared view. Although prior experience with desktop virtual environments led to an ability to adapt to pointer-based interaction, prior experience of mouse and pen interaction resulted in the gestural interaction feeling *unnatural*. Finally, the general ease of interaction provided by the system tended to encourage experimentation and play in the environment and the exploration of boundaries, and object creation was observed as resulting socially constructed notions of ownership.

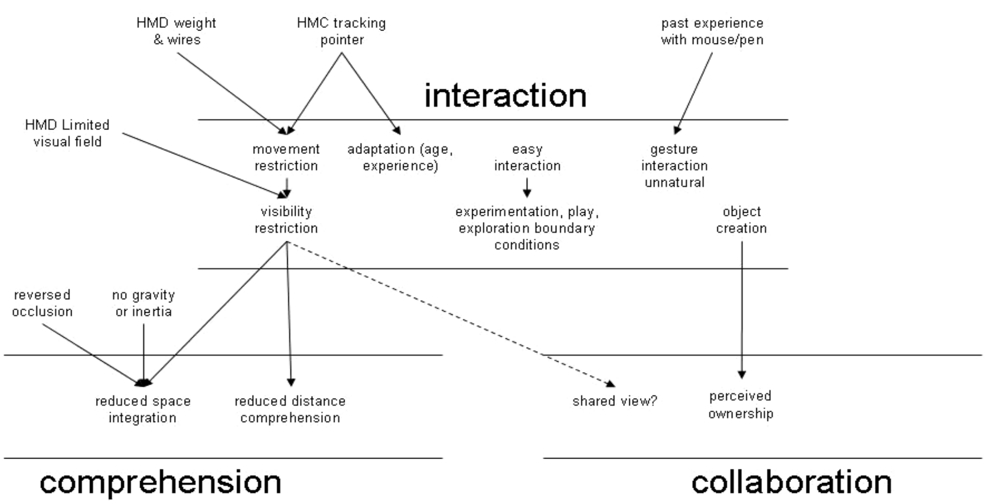

Figure 8: Interrelationships between factors in interaction, comprehension and collaboration.

4.2. Designing with a live movement simulation

In the following sections we describe tests designed to evaluate the impact of the ARTHUR environment with simulated pedestrian movement on the level and degree of collaboration between users.

Single user test

The evaluation tests started with an assessment session, an exploratory task was carried out, in order to evaluate the potential of the ARTHUR AR environment, augmented with simulations of pedestrian movement, and investigate the way it might affect the design process. The interaction techniques were restricted to moving two blocks by moving the attached placeholders.

Test protocol

A user was first given a short period of training and time to get used to the system, and then was asked to create a specific configuration taking into account the appearance of agents that move like people on the design table.

Results

Observations at the early stage of the agents integration was considered only as preliminary and a part of an early prototyping development process. However, the results of these tests proved to be very useful as they provided us with a wealth of observations which allowed us to improve the test sessions and objectives. Early observations indicated that the agents' speed and number were vital for defining the level of engagement and interaction with the agents. Moreover the subject pointed out that the integration of the 2D analysis of the movement (agents' traces) in the ARTHUR 3D environment is desirable as it helps understand and compare the various design solutions. Currently the agents' traces appear only on the 2D window in the agents' software **(**Figure 9).

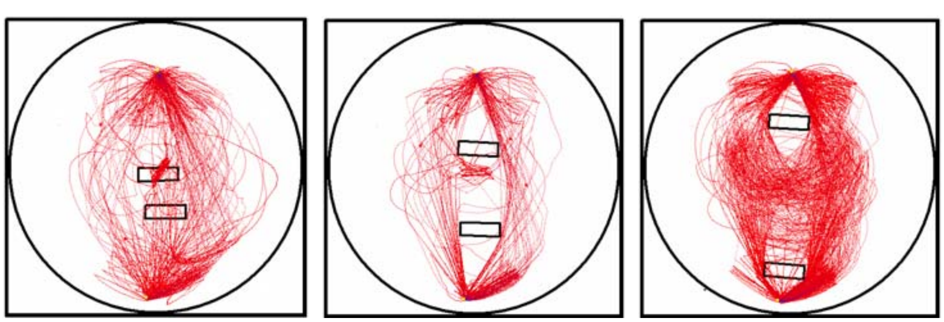

Figure 9: Changing the distance between the objects will change the 2D analysis of the agents' traces.

Multi user test-3 design sessions

Three design sessions were developed as an attempt to assess the impact of the real time interaction with the agents on a designer's approach to a design problem. In each session two users were asked to collaborate and construct a simple design solution using four walls as follows:

- The first session was conducted in a physical environment containing four fixed physical objects. Users were given four walls with which to construct the design solution (Figure 10. Left).
- The second session was run within the ARTHUR AR environment, augmented with ten spatial agents that responded dynamically to the changes in locations of objects on the table **(**Figure 10**.** Middle**)**. Like the first session, the AR environment had four fixed digital objects; in addition, four virtual walls could be used to construct a design solution. These virtual walls were attached to the PHOs and so could be relocated by moving the PHOs. There were also two additional fixed digital blocks, which represented the entry and exit point of the agents on the table UG - analogy to the Under Ground station. Agents move towards open space choosing a destination at random from the available space and walking towards it: their final destination is the UG.
- Finally the third session, which was again, conducted in the physical environment (Figure 10.Right). Users were asked in this session to go back to the physical environment, and try to reflect their AR experience, think of a design solution and then compare between the first and the third session.

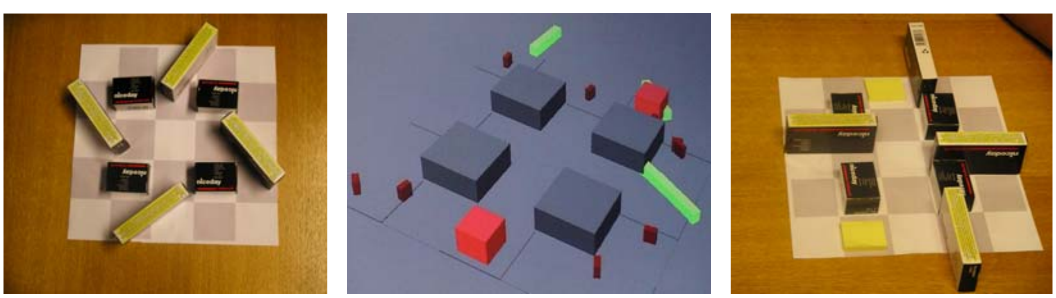

Figure 10: Experiment with 3 different design sessions.

Test protocol

Each experiment consisted of the three design sessions, described above. Three groups of designers were invited to go through the experiment; each group consisted of two collaborators, none of the users had any previous knowledge of the system. A brief description of the system was provided before starting the experiment. The form of collaboration was observed and notes were made of the difficulties the users experienced. The interaction, along with follow-up discussions, was videotaped for subsequent analysis with the consent of the subjects. This provided the researchers with a rich record of the complex setting, covering the interactions and difficulties experienced. More detailed feedback was documented in a form of a questionnaire. The observations reported here are mainly qualitative and derived from the video analysis of participants' interactions, discussions and questionnaires.

Results

Users' observations in the first design session indicated that designers were thinking of the design problem as a composition, trying to organize the walls in relation to the surrounding space, with less emphasis on other aspects such as movement.

When users were faced with simulated pedestrian movement, in the second design session, their design approach changed (Figure 11 and Figure 12).

Movement in space became very essential and had a direct impact on the way designers perceived and understood the design problem. Users began to observe agents' behaviour and their reaction towards movement of the walls within the space.

In this respect two key factors seemed to be very crucial: scale and time. As a result, and after watching agents move on the table for a period of time, users became immersed and therefore part of the interaction space: "Have you seen that guy (agent); as he saw the wall he turned 90 degrees in the other direction" [25]. Users began to alter agents' movement pattern by moving walls to different locations and this influenced the emerging design (Figure 12). These interactions involved both designers and simulation agents and as a result this increased the level of collaboration.

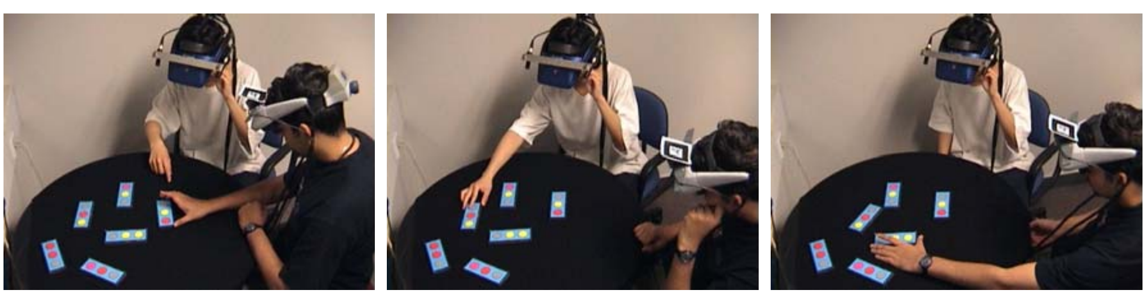

Figure 11: Interactions in session 2

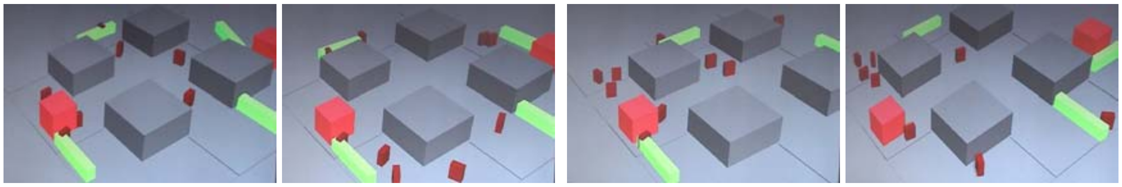

Figure 12: Interactions with the agents' simulation in session 2.

In the third design session, users were asked to go back to the physical setting and rethink the design. We realised that their approach to the design problems had changed after the second session and the interaction with the agents. At the beginning of this session, all groups asked for two additional physical objects to add to the model. These were equivalent to the UG (Under Ground Station) in the AR environment, which represented the entry and exit points of the agents. It seems that the presence of the UG helped designers to imagine the agents' behaviour and this encouraged discussions and collaboration.

Unlike in the first session, the design approach in the third session was less focused on composition but was rather a combination of different factors strongly influenced by the perception of movement patterns (Figure 13).

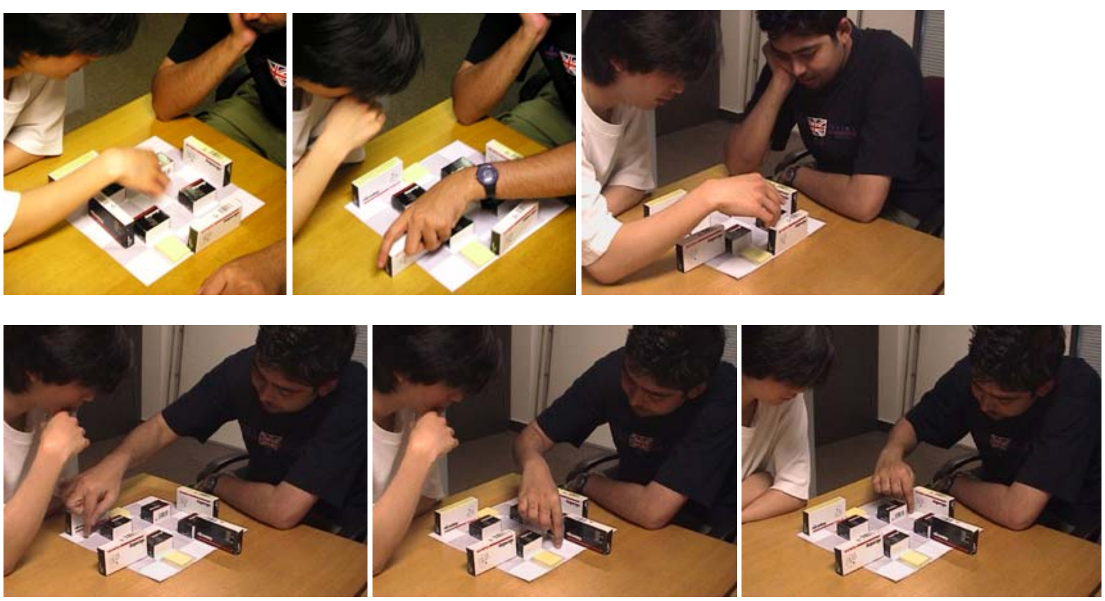

Figure 13: Interactions in session 3, with emphasis on movement.

Results from observation of the design sessions indicated that, whilst the movement of an individual agent was not necessarily an aid to understanding the spatial configuration, the overall movement of a larger number of agents was quite significant, which enabled users to make more informed decisions.

Subjects found the system to be both enjoyable and offer a potential for collaborative design and it appears that the interaction with the agents on the design table not only influences the way designers understand and design space, but also changes the way they approach design with physical models. Before experiencing the interaction with the agents the designers used a conventional way of designing. Conversely, the appearance of the agents on the design table encouraged the users to understand structures within space as a dynamic experience rather than a static one -through agents moving between spaces [25]. Figure 14 summarises the results by representing relationships between the agent simulation and interaction, collaboration and comprehension. The figure shows that the simulation of agents promoted cycles of observation and experimentation/playing i.e. reflection in action [3]. This in turn resulted in the designers experiencing greater immersion in the problem and an increased and more equitable collaboration. Finally, changes in the speed and number of agents had an effect of the designers' comprehension of the problem in terms of their appreciation of its dynamic qualities i.e. movement.

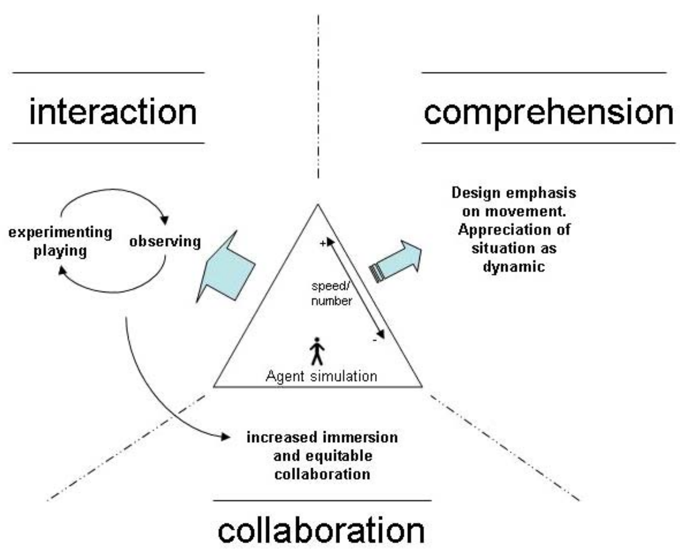

Figure 14: The impact of agents simulation on interaction, comprehension and collaboration.

4.3. MicroStation within the ARTHUR environment

The MicroStation / ARTHUR integration was evaluated informally due to the early stage of the integration.

A number of end users and developers tested the integration and were generally positive.

The ability to natively view existing MicroStation models, with no translation issues was felt to be very valuable. Navigation was found to be intuitive, though there are problems with jitter and offsets.

However the main benefit was the ability to create new MicroStation geometry directly, using powerful MicroStation tools (Figure 15). Again, jitter and offsets in the 5DoF pointer made the task difficult at times, but most users could successfully draw geometry directly in 3D, which they found to be a powerful concept.

Figure 15: Interactions with MicroStation menus in the AR environment.

The main limitation was the inability of the system to display MicroStation's native dynamic feedback during creation. Although alternative feedback was provided by the ARTHUR system, the subjects looked forward to Bentley making the modifications to MicroStation to allow ARTHUR to capture and display native dynamics. There were also concerns about the complexity of the system, and the size and usability of the pointer, which needs to be addressed in future developments.

5. DISCUSSION

Every new design medium brings to light insights into the design process. In the following sections we will describe main findings from the system in use related to three different aspects: Collaboration, presence and CAD/ARTHUR integration.

5.1.   Collaboration

Our findings from various forms of user evaluation tests suggest that ARTHUR may help throw light on the way that designers collaborate.

System evaluation at the early stages in development and integration was surrounded by technical glitches and inconsistencies, and it was clear that these affected a user's ability to evaluate the system as a whole.

Having said that, we observed that after a short period of training the subjects were able to use placeholders, pointers and gestures effectively. All subjects found the system to be enjoyable and it appears that the new AR medium seems to hold out a prospect for quite different ways of working. Two different kinds of behaviour were observable in our user tests of collaboration. In the first, one member of the team would take charge of the process, and direct actions. In the second, collaborators began to play games. Games were played by moving objects to affect movement patterns and consequently this increased the level of collaboration (Figure 16 and Figure 17).

Figure 16 playing games influenced the emerged design.

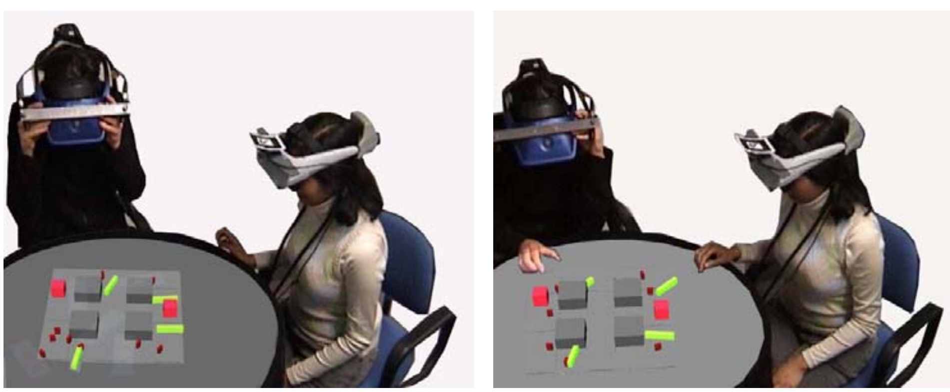

Figure 17 Users' were immersed watching the agent moving on the table.

Playing such games, particularly where they involve simulations of functional performance, may also promote learning. Our findings to date suggest that if technical and human factors barriers can be overcome, augmentation of the real world by digital interactive media may lead to new forms of genuinely collaborative form generation. One consequence of this is that design education may need to begin to learn some lessons from time based performance media about how to train designers to collaborate and play [4].

5.2. Presence

In ARTHUR user tests were conducted at regular intervals for usability by the end users of the project. The tests are primarily focused around the control of virtual objects via PHOs and the use of pointers to creation and manipulation of forms. The tests of the ARTHUR system are carried out by having test subjects go through pre-defined storyboards and having them elaborate their actions by *thinking aloud*. We have hereby obtained knowledge on especially the design of the user interface but also on technical aspects, e.g., how big the fields of view in the cameras and HMDs should be. We have not, however, made any tests that have been formulated around the concept of presence. It appears that the successful use of AR (augmented reality) technologies assumes a feeling of presence – of being there – on part of the user [26]. This is not necessarily easy to achieve and it may depend on many different factors. When operating with augmented world the real world objects and the digital objects are mixed and are required to be perceived simultaneously and this may assume presence in both worlds at the same time. A conflict as to the role of presence in such cases seems apparent, and questions could be whether this in itself is prohibitive for successful operation, or – in the other "extreme" – whether it is possible for these two requirements for presence to somehow support and/or reinforce one another [27].

In ARTHUR some factors may potentially be hindrances for the feeling of presence. These could include various aspects such as the restrictions imposed by the HMD design, objects viewed through a relatively narrow field of view provided by the headset or the appearance of the virtual objects as always superimposed on real objects, especially on user's hands, which may lead to a loss of the feeling of the virtual as existing within the real world.

The project argued in its outset that the real world setting at the round table would be augmented with a virtual world. We find, however, that when it all works, we may have a situation that is more appropriately described with opposite roles of the two worlds. i.e. presence at the building site (virtual world) is augmented with a *social feeling* of being there together. The social feeling of presence established in the real world is transferred to the collective feeling of being together at the virtual building site. Hence, we may have an example of augmented virtuality rather than augmented reality. Another issue which might affect the sense of presence and hence needs be taken into consideration when designing an AR environment is "attention tunneling". Attention tunneling happens when user's attention is focused on the area cued, at the cost of other areas. Other information in the table outside the cued area may be missed. Dopping-Hepenstal pointed out that “military pilots fixated more frequently on information presented on a HUD (Head-Up Display) at the cost of scanning the outside scene” [28].

The above mentioned description on presence have made us aware of the fact that for development of sophisticated interfaces, one often may use formulation in terms of presence as well as insight from presence research to structure important priorities in design.

5.3. ARTHUR/CAD integration

On the CAD integration level we report on an early stage in the CAD integration development process. Early feedback suggest that integrating CAD within the AR environment will allow to overcome limitations related to current CAD integration to AR or VR- based on exporting CAD data into different 3D graphics format like VRML 97, which has several drawbacks, e.g. loss of geometry or precision and the loss of semantics. Most importantly no real-time interaction or modification is possible without recursively converting between the different file formats.

Moreover it appears that the integration of CAD into ARTHUR raises complex issues related to designers' input and the interaction techniques within MicroStation and to how designers use the interface and interact with the created form within the AR environment.

One vital issue is related to accuracy, as a key issue to CAD modelling and how this is translated within the AR environment. In the AR environment designers interact with volumes without being involved with accuracy; to meet accuracy requirements, alternate techniques must be explored. Another issue that needs to be addressed is related to the new input data and how a classic 2D interface deals with input from various devices to manipulate a 3D datasets especially within the framework of providing natural interaction with virtual objects in a 3D collaboration environment.

To cover these issues therefore, a range of experiments should be conducted, using various interface mechanisms.

6. CONCLUSIONS AND FUTURE WORK

This paper demonstrates that the conventional view of CAD in architectural design is changing. We present ARTHUR in an attempt to bring the computer – as an interactive and creative medium in its own right – onto the design table to support designers working collaboratively with seamless interaction techniques. The integration of simulated agents' movement analysis is described together with existing CAD tools. Initial results from early forms of user evaluation suggest that ARTHUR may help throw light on the way that designers collaborate, and it appears that creating architectural forms within the AR environment became a game that users enjoyed and consequently this increased their level of collaboration [4]. Tests at CeBIT went a long way towards underpinning this belief. Although many of the users were not trained designers, the general notion of *playing around* with the system was realized by most subjects. Future tests will build on the experience gained from CeBIT test runs and will focus on trained architects and designers.

Building on the game metaphor, we have constructed design experiments in an attempt to explore the potential of real time interaction with simulated pedestrian movement on the design table. Observations of designers going through a cycle of reflection and action with the agents suggest that the integration of the pedestrian movement simulation played a vital role in exploring possible design solutions and encouraged different ways of thinking of a design problem. We believe that understanding of the design problem largely emerged through designers' observation of the agents' behavior and their interaction within the environment, characterizing an important dimension of the illustrated approach. This is supported by Negroponte "While a significant part of learning certainly comes from teaching… major measure comes from exploration, from reinventing the wheel and finding out for oneself . . . by playing with information, .., the material assumes more meaning" [29]. Augmenting the scene with simulations of pedestrian movement supports this, and it seems that an additional visualization of the agents' traces in the 3D environment would help give the designers a more informed impression about the space.

In this paper we have also reported on an early stage in the CAD integration development process. However, it is clear that the integration of CAD into ARTHUR raises complex issues related to designers' input and the interaction techniques within MicroStation. To cover these issues therefore, various experiments should be conducted, especially within the framework of providing natural interaction in a 3D collaboration environment using gestural input [25].

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