EXPLORING THE EFFECTS OF INTRODUCING REAL-TIME SIMULATION ON COLLABORATIVE URBAN DESIGN IN AUGMENTED REALITY

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Abstract. We report a study using ARTHUR, an augmented reality system in which simulated pedestrians (agents) interact with design proposals during architectural design and urban planning. We looked at the effects of the agents on how designers used the system. We found that the simulation encouraged complex integration of design and review which took the designers in unexpected directions. It also reduced the extent that participants 'envisioned'. Participants used the agents in many 'design experiments', but unexpected agent behaviour could be frustrating, creating a tendency for subjects to block or corral agents (rather than create opportunities). We discuss our findings.

1. Introduction

As a design-support technology, augmented reality (AR) offers impressive possibilities for designers. Using AR, three dimensional models can appear as if on a physical meeting table. These can then be collaboratively developed in ways impossible with a physical model. Also, computational simulations of complex, real-world phenomena can be run whilst designers simultaneously explore design possibilities. The potential benefits of these possibilities has resulted in research projects exploring AR to support common-view, collaborative architectural design and urban planning with 3D computational simulations (for example, URP (Underkoffler & Ishii, 1992) and MousHaus Table (Huang, Yi-Luen Do & Gross 2003)). Studies of people using such systems can reveal how these new possibilities affect design processes, as well as providing a source of reflection on the nature of design (Gero *et al.*, 2004) and how systems might be effectively deployed. So far little work has explored what these effects might be.

We report a study of ARTHUR (described in Fatah gen. Schieck et al., 2005), an Augmented Reality system that enables designers to work together

while simulated pedestrians interact with their design. The study explored how a real-time simulation of limited complexity viewed from a 'God's eye' perspective in AR affected the way users with architectural and urban design experience approached design problems. In subsequent sections we describe ARTHUR as configured for the study and the study methodology. We then report and discuss our findings.

2. System Overview

ARTHUR supports collaboration in architectural and urban design review sessions by projecting a virtual model onto a real round table. The model can be viewed by multiple users using see-through AR glasses. A pedestrian simulation allows the consequences of design changes to be evaluated while the design is being manipulated. Figure 1 shows how the model looked for one subject during the study. The dominant grey area represents a city square surrounded by buildings. Objects in the square represent street furniture and amenities including market stalls (blue striped canopies), two tube exits (top left, bottom right), a toilet (top right), and a play area (bottom left). Simulated pedestrians (agents) appear as red domino-shaped blocks.

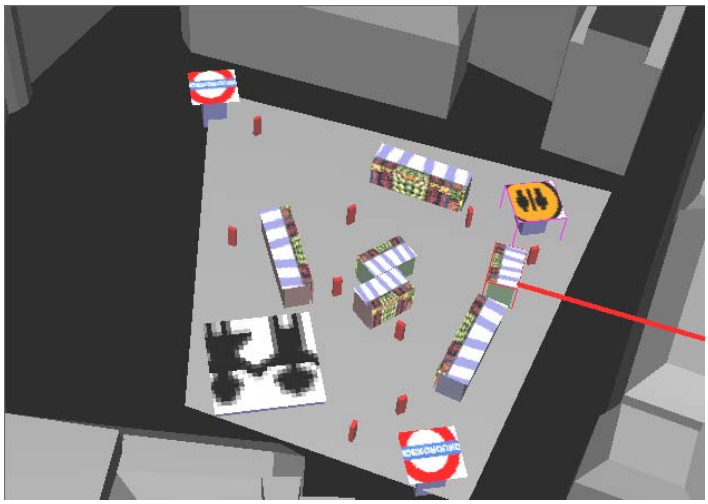

Figure 1: A view of the market square using ARTHUR.

For the current study, manipulation of virtual objects was supported using modified mice (one per user) which were mapped to pointers in the virtual world (shown as a continuous red line in figure 1). With a pointer users could:

- select objects (pointing and clicking the left mouse button);

- move objects in the XZ plane (move mouse in the XZ plane when object is selected); and
- rotate objects (rotate mouse around the Y axis when object selected).

Agent movement was based on a combination of exploratory and goal-directed behaviour. In the model, the underground exits and the toilet acted as entrance/exits. At each step, an agent would judge the longest line-of-sight within its field of vision and turn towards it. After ten steps, if an exit fell into view the agent would move towards it and exit the model.

3. Method

12 postgraduate students and researchers in architecture and urban planning at UCL, London were given training with ARTHUR before working in pairs to perform two market design tasks in a cross-over study design. The first task phase was designated 'July' and the second 'August'. For comparison, each task was first performed without and then with pedestrian simulation (4 trials in all). Each trial required subjects to arrange market stalls into a 'good' design around the remaining amenities (fixed). No time-limit was imposed.

Post-task interviews were used to identify emergent themes before an analysis of subjects' dialogues using summarised narratives and coding of conversational 'turns' (agreed by two independent coders). Both qualitative and quantitative analyses were performed as described in the next section.

4. Findings

4.1 PEDESTRIAN SIMULATION PROMOTING PEDESTRIAN FOCUS

During post-task interviews, subjects reported that the simulation did not increase the extent to which they considered pedestrians, but it did affect the *way* they considered pedestrians. They considered that their priorities changed towards promoting agent visits to market stalls. In fact, there was a significant increase in discussion about pedestrians between *without* and *with* agents conditions (one-tailed Wilcoxons, $p < 0.05$). There was no difference between the 'no agent' conditions before and after simulation.

4.2 RELATING TO AGENTS

Following subjects' reports that the simulation changed how they considered pedestrians, an exploratory analysis was performed to see how this may have been revealed in subjects' conversations during the trials. Before the simulation, subjects described pedestrian behaviour and experience in both third-person (*e.g.* '*they* can also buy something from the

market'), and second-person (*e.g.* 'if *you* get off the train, *you* can see…'). When agents were introduced, discussion went almost exclusively into the third-person.

Another aspect of how subjects related to agents was that they often made inferences about the underlying basis of agent behaviour. This was done either in terms of how the system might have been 'programmed', or by hypothesising about the agents' mental lives. For example,

S1b: Erm… the agents are very slow aren't they?

S1a: They just want their time.

S1b: I see what they're trying to do…

4.3 INITIAL DESIGN CONCEPTS AND REFLECTIVE ACTION

At the start of each trial, subjects almost always agreed a broad design idea. This idea (apparently corresponding to Darke's (1978) Primary Generator) prioritised either an abstract form (*e.g.* a 'street' or a 'square') or specific properties (*e.g.* access or visibility). In the second run (with simulation) of each problem, the primary concept was to recreate the previous solution as a starting point. Five subject pairs explicitly conducted such 'experiments', and all pairs reflected on agent behaviour in evaluating their prior designs.

4.4 USING DESIGN TO CONTROL BEHAVIOUR

The longer participants worked with the agents, the more agent behaviour could appear odd or even frustrating. The agents did not necessarily interact with the markets as the designers intended. (In the simulation, stalls were not 'attractors', and were only visited through chance encounters).

The agents' apparent lack of interest in the stalls frequently led the designers to refocus designing towards encouraging agents to the stalls. Where they previously talked about creating space, they now used market stalls to corral movement. Every subject pair explicitly used the stalls to direct agents at some point, and directing pedestrians (or proxies) was discussed 23 times in total, 17 of these being during agent simulation.

This refocusing of design goals tended to divert attention from, or compromise, the primary design concepts. Two pairs dropped their initial design concepts entirely and focused on getting agents to behave acceptably. One group decided to ignore the agents. Five of the six pairs made explicit the tension between designing 'well' (or simply "designing") and getting agents to behave desirably.

4.5 ANALYSIS OF SOLUTIONS

An analysis was performed to see whether the shift in priorities towards visiting stalls translated into measurable differences in design solutions.

Pedestrian simulations were run on all trial solutions (10 agents for 1000 agent 'steps') with movement mapped to cell counts in a superimposed grid.

Stall front and rear proximity figures were calculated as the total steps occurring within a one-stall-area. The results (summarised in fig. 2) show a steady increase in front of stall visits and a general decrease in rear of stall visits. This supports the idea that subjects worked to increase front-of-stall visits, decrease rear-of-stall visits and that performance generally improved.

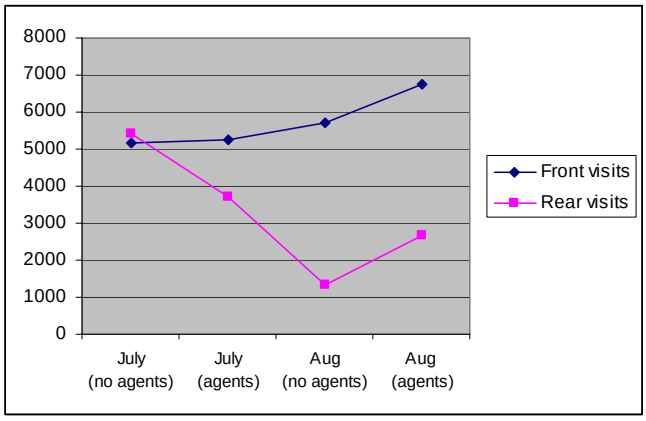

Figure 2. Total front and rear stall visits across all subject pairs for each trial.

5. Discussion

This study aimed to explore the effects of a real-time 'God's eye' pedestrian simulation in Augmented Reality urban designing. Our results suggest that using simulations in AR can have a significant effect. We make two principal issues which here we will discuss: encouraging ad-hoc design, and promoting an 'objective' design perspective when designing with people in mind.

5.1 AD-HOC DESIGN

With the agent simulation, designing was more reactive and ad-hoc. Subjects reflected on agent behaviour, diagnosed problems and progressively modified their designs. In this way the simulation informed local and global experiments, including the debugging of previous design ideas. The increase in stall-front visits and the more pronounced decrease in stall-rear visits demonstrates a developing interest or ability to address agent behaviour and related requirements. But this created a tension with *a priori* design concepts and these could be stretched to breaking point. Under this tension, some subjects dropped the initial concept, some ignored the simulation.

5.2 'OBJECTIVE' DESIGN PERSPECTIVE

The simulation reduced subjects empathizing with pedestrians. The simulation represented movement as autonomous and aggregated. The reduction in second-person speech and of 'envisioning' suggests that this promoted a less empathic perspective, with subjects tending more towards 'crowd control' than designing an experience. Imagined walkthroughs were still possible, but were perhaps problematic under the visual 'noise' of a simulation. Whichever the case, the simulation encouraged an objective view of pedestrians. This may be an asset where aggregated pedestrian behaviour is of primary concern, but it also draws attention to a distinction between designing for people, and say, considering wind or light (which have also been simulated in AR). Depending on the design values in operation, designer-manipulated first-person walkthroughs may encourage a different kind of designer evaluation.

Designing with real-time, autonomous simulations through AR has the potential for adding value to urban planning and architectural design beyond traditional design modalities by providing a source of reflection. Features of designs can be revealed and responded to early. This study has observed how such a simulation promotes ad-hoc design, and also an 'objective' perspective in designing for people. In conclusion, the study raises questions we hope to address in future work. It raises questions about different kinds of simulated behaviours and how this might influence the trade-off between design 'ideals' and design 'reality'. It also raises questions about designers' empathy with users of their designs and how this might relate to first-person perspective walkthroughs compared with 'Gods eye' observations of autonomous activity.

References

Darke, J: 1978, The Primary Generator and The Design Process. In: Rogers, W.E., Ittelson, W.H. (eds.) *New Directions in Environmental Design Research: Proceedings of EDRA 9.* Washington: EDRA. pp. 325-337

Huang, C Yi-Luen Do, E and Gross, D: 2003, MouseHaus Table: A Physical Interface for Urban Design. *16th Annual ACM Symposium on User Interface Software and Technology (UIST)*, Vancouver, B.C., Canada, ACM Press.

Fatah gen. Schieck, A Penn, A Mottram, C Strothmann, A Ohlenburg, J Broll, W Aish, F and Attfield, S: 2005, Interactive Space Generation through Play: Exploring the Role of Simulation on the Design Table. *IJAC: International Journal of Architectural Computing*, 3(1), a Multi-Science Publication.

Gero, JS Maher, ML Bila, Z Marchant, D Namprempree, K and Candy, L: 2004, Studying Collaborative Design in High Bandwidth Virtual Environments. *CRC Construction Innovation – Clients Driving Innovation Conference*.

Underkoffler, J and Ishii, H: 1999, Urp: A Luminous-Tangible Workbench for Urban Planning and Design. In: *Proceedings of CHI 99*, ACM press.