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Reducing Fragmentation in Telecollaboration by Using IPT Interfaces

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Abstract

Telecommunication systems, such as AccessGrid, allow collaboration across a distributed group. However, these systems typically introduce fragmentation into the view of the shared environment. Many have found that IPT systems offer several important advantages above other display technologies in supporting distance working. This study focuses on fragmentation, which has previously been shown to induce problems in efficient object referencing within a shared virtual environment accessed through desktop displays. We have attempted to repeat the experiment while varying the display type. The results reinforce previous studies by showing a significant improvement in task performance when the entire team uses IPT displays. Further, the results provide an original contribution by demonstrating a relationship between the scale of this performance and the spatial extent of the task. We postulate that this is due to a reduction in fragmentation when compared to other display technologies.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques

1. Introduction

Communication technology allows collaboration across a distributed team, offering many advantages in today's globalised socio economic information culture. Characteristics of display technology can play a major role in the effectiveness of distant teamwork. A key factor is fragmentation of the shared environment.

When collaborating through a traditional telephone, the shared environment can only be perceived through sound and imagination that sound and particularly conversation conjure up. With teleconferencing technologies, such as AccessGrid, people can look into each other's world. They therefore have a shared space, however uneven ability to both perceive it and interact with it. These technologies can also share software applications, although typically only one person can interact with the software at a time. More fundamentally, the team is in no way immersed in the information environment, which limits the naturalness, and we would argue the performance, of communicating attention and interaction [HFHB01, Art96, Kje01, LV02, PWBI98].

Collaborative virtual environments (CVE) allow people to share a space in a fair and spatially unconstrained manner. This helps to reference objects within the shape and to indicate focus of attention or activity. A previous well known study by Hindmarsh et al. [HFH*00], showed that fragmentation was still a problem within CVEs and linked this to the low field of view offered by desktop interfaces. More recent studies have used IPTs to interface to CVEs and have found them to be very effective [SSA*01, RWO*04, HSS*05]. We are part of a growing community that believe networked IPTs bring us considerably closer to resembling a face-to-face meeting between a distributed group. A growing wealth of research adds weight to this argument.

When compared to desktop displays, linked IPTs have been shown to improve capabilities [RWO*04, HSS*05], impact on role, increase feelings of contribution and collaboration and increase task performance. We suspect that these improvements come from a set of factors that together allow people to consciously and subconsciously use their body in a natural way to observe and interact with the environment and avatars within it. Recent studies with linked IPTs have reported not noticing the changes of human behaviour induced by fragmentation, notated by Hindmarsh et al. [RWO*04, HSS*05].

The aim of this work is to contribute to the understanding of why IPTs seem better at supporting distance team work, through testing their impact on fragmentation against that of desktops in an adaptation of a well known study.

This paper adopts the classic structure of following this introduction in section 1, by defining the experimentation in section 2, presenting results in section 3 and drawing conclusions in section 4.

2. Experimentation

The experiment is based on that of Hindmarsh et al. [HFH*00] and extends it by comparing the use of IPT displays to desktops. This short paper only reports on the quantitative measure of task performance.

2.1. Environment

The environment has been modelled to resemble that of Hindmarsh's experiment [HFH*00] as close as possible. A large room is cluttered with a collection of chairs, some of which are visually distinct, and other more distinctive furniture, such as a standing lamp, computer-desk, television and HiFi system. Most of the furniture could be uniquely identified verbally but it was suspected that reference to it within the context of the scene and particularly through referential gestures would improve the performance of communicating its identity. Each object can be moved within the environment through direct manipulation. Figure 1 shows the layout of the environment and gives an indication of the active area during each task.

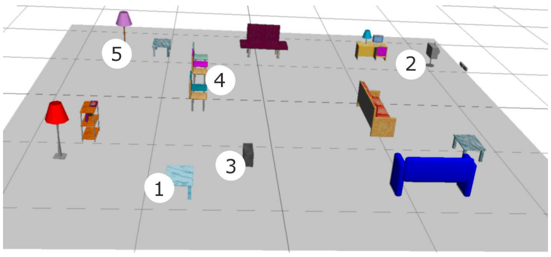

Figure 1: *Layout of the environment. The numbers indicate the area of attention within each task.*

2.2. Task

Like the earlier experiment [HFH*00], organising the furniture within the room is divided into a number of sub tasks. These indclude:

1. Bring attention to the marble table.
2. Move the television.
3. Rise the system from the floor.
4. Rearrange the chairs.
5. Move the standing lamp to another part of the room.

These tasks differ in requirements for perception, navigation, communication and interaction. They also differ in typical spatial extent. We suspected that factors of display characteristics would impact distinctly across this set of tasks. Gesturing towards objects and carrying them are shown in figure 2 within the "Move the television" sub task.

2.3. Display configurations

Two display types have been used, desktop and IPT. These were paired into three configurations desktop-desktop, IPT-desktop and IPT-IPT. The IPT trials were carried out between displays at the Universities of Salford and Reading in UK. All other trails were carried out at Salford. Both desktop interfaces comprised an eighteen inch monitor, a 6 degree-of-freedom spacemouse, keyboard, microphone and speaker. Both IPTs comprised a three wall and floor display, motion tracking of head and primary hand, wand with joystick navigation control, speaker and microphone. The Salford IPT used magnetic tracking technology, while that at Reading used a combination of ultrasonic and gyroscopic.

2.4. Embodiment

In all cases, the remote user was embodied by a jointed avatar. This character was modelled using realistic dimensions for limbs and a 3D scan for the face. Image capture and texture mapping was used for face, other skin, hair and cloths. Movement of the avatar is controlled through three points: head and both hands. These were tracked within the IPT, and controlled through the spacemouse on the desktop systems. However, one of the hands was not connected to input for this experiment to simplify comparison between desktop and IPT. Torso position and orientation, as well as articulated arm movement are then improvised from these points. Inverse kinematics are used to improvise arm articulation. The facial expression is static. The avatar can nod and shake its head. If the head shaking reaches a certain threshold the body of the avatar will start to swivel. Audio communication augmented the visual embodiment but was not spatially tied to it.

2.5. Platform

The Immersive Collaborative Environment (ICE) [WRO04] was used as a test platform. We originally intended to use a more widely adopted test platform but found that those available were unable to render the populated and cluttered environment at frame rate above the level of human perception on the available graphics computers.

2.6. Computers

The desktop PC systems were single processor machines, whereas the IPTs were run from SGI Onyx2 multipipe multiprocessor computers. Reading ran four walls from two pipes and used four processors, whereas Salford ran each wall from a separate pipe and used twelve processors.

2.7. Network Conditions

Typical ICMP ping tests between the desktops and desktop and IPT were one millisecond. Similar tests between the two IPTs yielded around 17ms. Network conditions were typical at the time of the tests.

Figure 2: *The scenario "Move the television" in the IPT-Desktop configuration: planning the task seen from the desktop (left), placing the TV as seen from the IPT (middle) and the TV in the final position as seen from the desktop (right).*

Table 1: *Measurements of task performance within the distinct display configurations.*

Task		Time taken in second of user pairs								Average
Deskop - Desktop										
1	Look at the marble table	136	33	43	47	61	18	21		51
2	Move the television	90	61	60	93	49	55	72		69
3	Rise the system from floor	80	72	70	107	42	60	37		67
4	Rearrange the chairs	95	112	102	130	145	120	85		113
5	Move the stand lamp to another place	117	70	78	73	38	79	69		75
IPT - Desktop										
1	Look at the marble table	63	41	22	43	20	50	16	24	35
2	Move the television	38	32	112	82	25	46	47	63	56
3	Rise the system from floor	71	40	85	98	58	42	52	34	60
4	Rearrange the chairs	186	160	80	120	113	76	98	75	114
5	Move the stand lamp to another place	50	52	88	60	70	31	67	56	59
IPT - IPT										
1	Look at the marble table	18	25	20						21
2	Move the television	26	50	80						52
3	Rise the system from floor	32	45	70						49
4	Rearrange the chairs	53	60	90						68
5	Move the stand lamp to another place	21	30	40						30

2.8. Subjects

Sixteen voluntary test subjects have been taken from MSc students and their friends. All have prior experience of computers and around half have knowledge of the principles of VR and some prior experience of IPTs. The gender distribution was roughly equal. At the time of writing, nineteen subjects have been tested but only six of these within the IPTs. People were shown how to use the system and given time to become accustomed to it before data was collected on their activities. This typically took around five minutes.

2.9. Measurement

Although we have recorded conversations and measured user experience through a qualitative questionnaire, this data has not yet been fully analysed and we restrict this paper to the quantitative measurement of task performance in terms of the time taken to complete each task.

3. Results

Table 1 shows the measurements of time taken in seconds for each user pair to complete a subtask when interacting trhough the various display combinations. One can recognise a large deviation in the values where desktop displays were involved. When observing the collaborating users how they interacted through the various interfaces, we could detect similar divergent behaviours.

During this trial and others [RWO*04, HSS*05] we have observed that glancing around the environment in the IPT is very natural, provided in a three wall configuration, the user's body is facing mostly towards the central wall. In comparison, viewpoint changes are cumbersome on the desktop and only occur as a conscious and deliberate action. Navigation within the immersive environment produces smoother and more efficient trajectories. On desktop displays where the viewpoint is tied to the avatar, the user keeps stopping to look around and adjust the trajectory. People can be seen to follow the gestures and gaze of others with their own gaze.

A graph of the above results clearly shows a consistent impact of display configuration on task performance, Figure 3. In all five tasks, exclusive use of IPTs outperforms an IPT-desktop pair which, in turn, outperforms exclusive use of desktops.

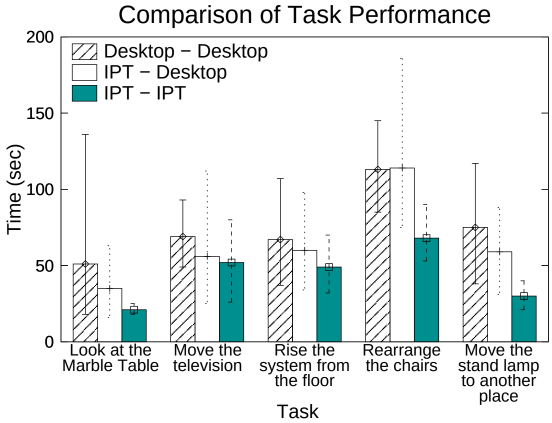

Figure 3: *Task performance compared over display device configurations.*

The reduction in task duration relative to the length of the task ranks as shown in Table 2.

Table 2: *Ratio between Desktop and IPT trials, this ranking correlates to the typical use of space in each task.*

Task	Ratio
Look at the marble table	0.40
Move the television	0.41
Rise the system from the floor	0.60
Rearrange the chairs	0.73
Move the stand lamp to another place	0.76

4. Conclusion

As we might expect from previous trials, these results show an increase in collaborative task performance from exclusive use of IPTs to interact within a 3D shared synthetic world. We have previously found that the natural use of the body in IPTs to reference and interact with objects increases both task performance and subjective impression of collaboration [RWO*04]. The original contribution of the results published here is an initial indication that the scale of this improvement is relative to the spatial extent of the task. From these results alone it is difficult to isolate the impact on navigation and on communicating. However, our observations of user behaviour convince us that the increase in immersion, and in particular the naturalness of viewpoint and its control impact on the performance of both finding an object or place within the environment and moving to it. We suspect that communicative gaze plays a strong role in the performance of demonstrating focus of attention. As the physical extent of the display is considerably less than that of the shared environment, this advantage is unlikely to be connected to the mode of navigation. A more likely contributing factor is the reduction in fragmentation, brought about by bring two people within the same shared space and allowing each to see where the other is looking and pointing from a natural perspective.

4.1. Near Future Work

At the time of writing we have not tested a sufficient set of people to provide conclusive results, however, these initial results are promising. A greater scale of test subjects is required to prove true statistical significance and we hope to have achieved this by the time of paper acceptance. We also intend to measure and plot the space used for each task.

5. Acknowledgements

References

[Art96] ARTHUR K.: Effects of field of view on task performance with head-mounted displays. In *Human Factors in Computing Systems* (Vancouver, Canada, 1996), pp. 29–30. 1

[HFH*00] HINDMARSH J., FRASER M., HEATH C., BENFORD S., GREENHALGH C.: Object-focused interaction in collaborative virtual environments. *ACM Transactions on Computer-Human Interaction (ToCHI) 7*, 4 (2000), 477–509. 1, 2

[HFHB01] HINDMARSH J., FRASER M., HEATH C., BENFORD S.: *Virtually Missing the Point: Configuring CVEs for Object-Focused Interaction*. Springer Verlag, London, UK, 2001, ch. Collaborative Virtual Environments, pp. 115–139. 1

[HSS*05] HELDAL I., STEED A., SPANTE M., SCHROEDER R., BENGTSSON S., PARTANAN M.: Successes and failures in co-present situations. *forthcoming in Presence: Teleoperators and Virtual Environments 14*, 5 (2005). 1, 3

[Kje01] KJELDSKOV J.: Interaction: Full and partial immersive virtual reality displays. In *IRIS24* (2001), University of Bergen B., (Ed.), pp. 587–600. 1

[LV02] LAPOINTE J.-F., VINSON N.: Effects of joystick mapping and field-of-view on human performance in virtual walkthroughs. In *the 1st International Symposium on 3D Data Processing Visualization and Transmission* (Padova, Italy, June 18-21 2002), pp. 490–493. 1

[PWBI98] POUPYREV I., WEGHORST S., BILLINGHURST M., ICHIKAWA T.: Egocentric object manipulation in virtual environments: empirical evaluation of interaction techniques. *Computer Graphics Forum 17*, 3 (1998), 41–52. 1

[RWO*04] ROBERTS D., WOLFF R., OTTO O., KRANZLMUELLER D., ANTHES C., STEED A.: Supporting social human communication between distributed walk-in displays. In *VRST 2004* (2004), ACM, (Ed.), pp. 81–88. 1, 3, 4

[SSA*01] SCHROEDER R., STEED A., AXELSSON A., HELDAL I., ABELIN A., WIDESTROEM J., NILSSON A., SLATER M.: Collaborating in networked immersive spaces: as good as being there together? *Computers and Graphics 25*, 5 (2001), 781–788. 1

[WRO04] WOLFF R., ROBERTS D. J., OTTO O.: Collaboration around shared objects in immersive virtual environments. In *8th IEEE International Symposium on Distributed Simulation and Real-Time Applications (DS-RT'04)* (October 2004), pp. 206–209. 2