Evaluation of a Mobile MR Geovisualisation Interface

F. Liarokapis

Coventry University, Cogent Computing Applied Research Centre, Department of Computer Science, Coventry, CV1 5FB, UK

Abstract

This paper presents experimental results of a mobile mixed reality interface designed for geovisualization of 3D realistic urban environments which allows dynamic switching between three visualization domains: a virtual reality; an augmented reality and a mixed reality interface to get the best possible representation for visual exploration. On each domain, four different types of geovisualisation and navigation aids can be superimposed including geo-referenced 3D maps, 2D digital maps, spatial 3D sound and 3D/2D textual annotations. Interaction is performed using keyboard, mouse, menus and tangible ways. To gather user requirements about urban and virtual navigation and to assess the effectiveness of mobile interface, a two-stage evaluation was performed.

Categories: Mixed reality, Geovisualisation, Virtual Reality, Augmented Reality, Mobile Computing.

1 Introduction

The need for advanced visualization systems is increasing continuously and as a result new and challenging applications are being developed. Geographers and computer scientists are slowly moving from two-dimensional (2D) to three-dimensional (3D) representations of which two characteristic examples are Goggle Earth and Virtual Earth 3D. The existence of advanced visualization techniques to represent geographic information has made it easier to provide academics and professionals with user-friendly navigational and geographic visualization (or geovisualisation) interfaces. 3D geovisualization is making use of a number of different technologies ranging from interactive computer graphics to customized geographical information systems. Moreover, due to recent developments in computer science, there are many new ways of creating maps based on software (i.e. photogrammetry) or hardware (i.e. laser scanning as LIDAR data) solutions. Advanced visualization tools, also known as geographic visualization, has allowed cartographers to do more than they were able to do on paper.

Augmented reality (AR) is a technology that merges virtual with real information in real-time performance [Azu97]. In an ideal AR environment, the user is able to see the real world with overlying virtual information (i.e. 3D objects, sound, 2D images, videos and metadata). In VR systems, by contrast, a virtual world replaces the real one with a complete synthetic one. Mixed reality [MK94] stretches on a continuum with the real world at one extreme and VR at the other, having AR in the middle. However, the majority of geovisualization systems make use only of 2D images/maps to generate user views [Hak02]. But a powerful feature that digital mapping can offer is the ability to use three dimensions including latitude, longitude and elevation. Elevation can be used to simulate an uneven map surface rather than a flat paper plane. Although dynamic 3D visualization can be manipulated in all sorts of ways, from radio wave propagation analysis to creating realistic backdrops for computer games, there are no user-studies on mobile MR geovisualisation interfaces.

To address some of the above issues a mobile MR interface, capable of superimposing different types of geographical information like 3D geo-referenced map, spatial 3D sound, 2D digital maps and textual annotations, is briefly presented and then evaluated. The interface allows users to switch interactively between three visualization domains: a VR; an AR and a MR interface to get the best possible visual representation of all the above types of geographical information. Interaction is performed using the UMPC keyboard and mouse, a graphical user menu interface and tangible ways. The assessment of the mobile interface is based on a two-stage evaluation and the results are presented.

2 Mobile Framework

A good overview of wearable mixed reality frameworks has been recently presented [PVT06]. However, urban geovisualization and 3D exploration can be very complicated since the level of complexity depends on the user preferences and the level of abstraction the topography provides. An ideal system, that would provide adequate services, needs to implement a combination of both egocentric and exocentric views. MRGIS [LBP06] is a C++ stand-alone MR application that was built on top of a generic AR interface [Lia07] and consists of four parts including *geographical content*; *3D model generation*; *interaction techniques*; and *content visualization* (Figure 1).

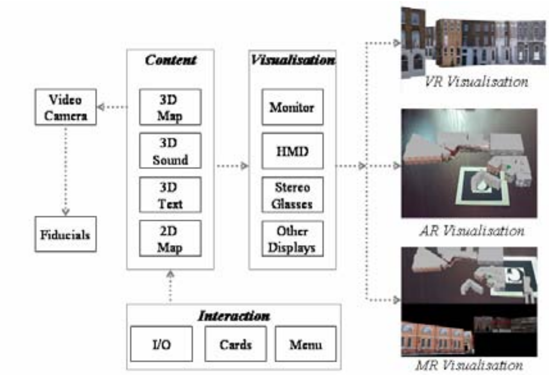

Figure 1: High-level architectural description

In terms of visualization, three domains have been implemented: a VR, an AR and a MR. On each domain, four different types of geovisualisation and navigation aids can be superimposed including geo-referenced 3D maps, 2D digital maps, spatial 3D sound and 3D/2D textual annotations. Interactions can be performed using the mouse or the keyboard of the UMPC, MRGIS user-centered graphical user-interface and tangible ways.

3 Expert User Evaluation

Expert-user evaluation is a popular method in human-computer interaction [TM05]. The literature also suggests that using three to five experts is sufficient to evaluate a system [Nie94]. A single evaluator can discover only 35% of the usability problems, whereas five evaluators can discover up to 75% of the usability problems. The expert user evaluation took place at City University in London with six expert users from different backgrounds including *geography*; *geovisualization*; *mixed reality*; *information retrieval*; *human-computer interaction* and *psychology* have been interviewed. The average time for each interview was 30 minutes and users aged between 30 to 50 years old. Two types of questionnaires have been disseminated including (a) general issues about pedestrian navigation and (b) testing of four hypotheses for virtual navigation.

3.1. Pedestrian Navigation Issues

Pedestrian navigation is a complex process and involves mainly perception and cognition issues. This part of the study, tries to gather user requirements regarding to some of the issues related to urban navigation such as: *user*; *environmental* and *external*. For the *user* related requirements, the speed of the navigator affects the navigation process and smooth or slow speed is preferred. The field-of-view is another important issue and having a view of the destination and the route is clearly an advantage. Eye-level of view is preferred and not the bird's eye perspective. The position of the user is crucial for navigation, and position of navigator is important (when making a decision) and changeable. Orientation is essential for navigation and relates to the field-of-view. In terms of the *environmental requirements*, road signs were found to be important especially when navigating in unfamiliar environments. This also depends on the mode of travel and the style of navigation. Landmarks were also found to be of great importance. If visual cues are used then landmarks become very significant objects. Regarding the *external* requirements, it was found that participants mostly use paper maps (2D maps) for urban navigation, like A-Z maps is commonly used when there is a street address. However, reading paper maps is difficult. Other results of the questionnaire suggested that the use of digital maps has become very common because the save time.

3.2. Hypotheses Testing

After completing the questionnaire the participants were given four different navigation tasks regarding a realistic virtual representation of Northampton Square at City University campus (Figure 2).

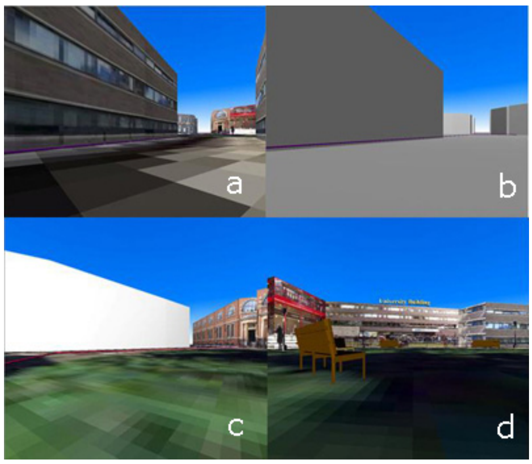

Figure 2: Hypothesis (a) correct textures, (b) no textures, (c) landmark textures, (d) full detail

When navigating in VR environment participants had to follow a virtual line, illustrating the 'beginning' and 'end' of the route. A brief overview of the recorded feedback is shown below:

A. Textured vs. non-textured 3D map: All participants agreed that the use of texture is an appropriate way for visualization in virtual environments. They did not like the 3D map without textures because the textured model was more realistic. However when they were navigating in the non-textured model they would not know where they were if they hadn't seen the textured model earlier. Finally, all concluded as using textures is more appreciated than using no textures at all.

B. Correct vs. wrong vs. landmark textures: Most the participants felt there was a difference between these two models but could not work what was the difference. They did not recognize if the textures were wrong in the second model. Most of them asserted that they did not like the mixture of textured and non-textured in the same model. The result of this task shows that the mixture of realistic objects (textures) and abstract objects (non textures) does not make the model pleasant to use and use of landmarks aids navigation. All the participants agreed that landmarks are very important to virtual navigation.

C. High resolution vs. low resolution textures: All the participants agreed that they did not feel any difference between high and low resolution models in terms of virtual navigation. The speed is important and if the level of speed is constant, high resolution could be chosen as better option. In general there is a no difference between the high and low resolution models. It would be better if high resolution could be used in a 3D environment but is not necessary.

D. High-detail vs. medium-detail vs. low detail: As far as the high detail map is concerned, participants preferred the full detailed model. Level of detail was sufficient and the virtual representation gave them a good idea about the real environment. The use of textual annotations that indicated buildings name was effective. It was also pointed that the extra street detail would be useful if used to distinguish one location from another. However, participants generally did not like having too much detail, preferred less but more realistic representation of the environment.

4 End User Evaluation

This evaluation was conducted to determine user needs during geovisualization and spatial exploration. It is believed that observing users while they are using the mobile MR interface it is an efficient way to gather data about the system usability [DF*04]. The user-testing conducted with 30 users, 15 male and 15 female, aged 18 to 43. The users assessed in different issues within the UMPC MR interface (Figure 3, top images) and obtained VR (egocentric, Figure 3 bottom left) and AR (exocentric, Figure 3 bottom right) views. Next, two questionnaires were to be completed after finishing the tasks and a semi-structured interview was conducted at last. The first included open ended questions about participants' personal information and the second included scaling and multi-choice type questions. The participants rated this comparison on a scale of 1 to 5 (1=not at all, 5=very much).

Figure 3: Participant setup (top), egocentric VR (left) and exocentric AR (right) (bottom images)

4.1. Results

The first comparison tested the overall satisfaction of VR, AR and MR interfaces in terms of geovisualisation and quantified which one is most satisfactory for visual exploration (Figure 4).

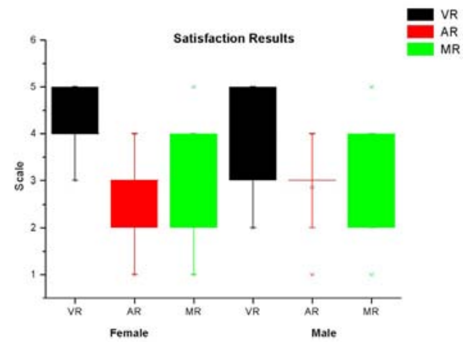

Figure 4: Satisfaction between VR, AR and MR

Participants visualized the same 3D map with each one interface and the highest score was recorded using the VR domain (M = 4, SD = 0.94686, SE = 0.17287) and almost the same for AR (M = 2.8, SD = 0.8469, SE = 0.15462) and MR (M = 2.8, SD = 1.18613, SE = 0.21656) domains. Next, they were asked to assess all of the above types including a VR map, a digital map, textual annotations and 3D spatial sound (Figure 5). Results illustrated that the 3D map (M = 4.2, SD = 0.8469, SE = 0.15462) is the preferred medium, next the textual annotations (M = 3.96667, SD = 1.18855, SE = 0.217), then the digital map (M = 3.76667, SD = 1.19434, SE = 0.21805) and finally the spatial sound (M = 3.5, SD = 1.3834, SE = 0.25257).

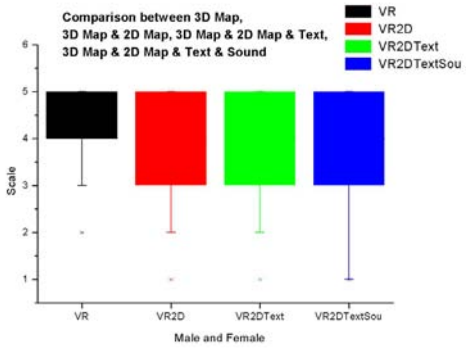

Figure 5: Comparison between VR map, 2D map, 2D text and 3D spatial sound

However, all participants indicated that the combination of all the above navigation aids is beneficiary and they would prefer it. The final test was a comparison of interaction techniques of the mobile interface (Figure 6).

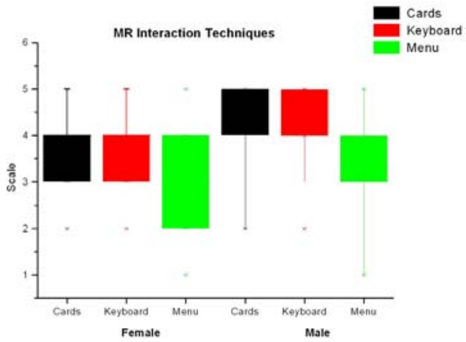

Figure 6: Mobile interaction techniques

A characteristic of the VR interface is operational only if the web-camera is in line of sight with the marker cards. This was designed on purpose so that all interaction techniques could be tested under the same umbrella. Most participants preferred the marker cards (M = 4.1, SD = 0.99481, SE = 0.18163), then the keyboard on the UMPC (M = 3.8, SD = 0.88668, SE = 0.16189) and finally the menu interface (M = 3.16667, SD = 1.17688, SE = 0.21487).

5 Conclusions

In this paper, a two-stage evaluation of a mobile MR interface designed for geovisualisation applications is presented. The expert user evaluation found that the speed, the field-of-view, the eye-level view and orientation are important issues in urban navigation. Environmental variables that played a significant role included the road signs, landmarks, volume of urban structures and weather conditions. In terms of external aids, paper maps are still preferred but the use of digital maps has become very common. In the end-user evaluation, for visual exploration the VR domain was the most successful whereas in terms of navigational assistance the combination of the VR map with spatial 3D sound and a 2D digital map with textual annotations was found to be the most effective medium. In terms of interaction, participants preferred the marker cards, then the keyboard and finally the menu interface.

Acknowledgments

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