Poster: A Comparative Study of Metaphors for Investigating Augmented Reality Artifacts

Kimberly Zeitz* Rebecca Zeitz† Congwu Tao‡ Nicholas Polys§

Advanced Research Computing and Computer Science
Virginia Polytechnic Institute and State University

Abstract

Augmented Reality applications allow users to view real-world elements augmented by virtual content. Providing appropriate manipulation techniques for virtual objects has the potential to enhance user performance, decrease task completion time, and elicit a more positive user experience. With a goal of establishing guidelines to inform the selection of manipulation metaphors for the development of AR interfaces, we compared physical and touch manipulation metaphors for zoom and rotation techniques. Qualitative and quantitative data on user preferences and performance were gathered from a within-subjects user study that utilized frame markers for registering and rendering 3D artifacts. Results indicated that the non-mixed metaphor interfaces performed the best with regard to task completion time, accuracy, and user preference in terms of intuitiveness and ease of use.

Index Terms: H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems—Artificial, augmented, and virtual realities;

1 Introduction

We conducted a user study exploring physical viewing and virtual object manipulation metaphors implemented with multi-touch screen interactions for AR interfaces. Each metaphor supports interaction techniques for object zooming and rotation (6DOF) of virtual 3D objects (e.g. cultural artifacts) through a tablet display from all sides and at different scales. This distinction between physical and virtual techniques set up several trade-offs and hypotheses about the naturalism of AR 3D user interactions.

In the 3DUI design space, one input device taxonomy distinguishes between the integrated and separated degrees of freedom (DOF) of input devices as the main classification criteria. The design space of multiple DOF devices is still largely unexplored, leaving room for the study of integrated and separated solutions or combinations of device manipulation techniques [3, 5]. Research has examined finding appropriate manipulation techniques and scenarios for user studies [1]. An Asus Infinity tablet was used in our study for its quality display and light form factor. When providing augmented material to users, ideally there would be seamless integration, enabling users to naturally interact with AR content. There are many approaches on how to reference the physical world and sync and manipulate AR content [6, 2, 4]. Successful design choices rely on user understanding of the mapping between what they wish to accomplish and how they can accomplish it.

*e-mail: kazeitz@vt.edu
†e-mail: razeitz@vt.edu
‡e-mail:tcongwu@vt.edu
§e-mail: npolys@vt.edu

IEEE Symposium on 3D User Interfaces 2014
29 - 30 March, Minneapolis, Minnesota, USA
978-1-4799-3624-3/14/$31.00 ©2014 IEEE

Figure 1: Application usage

Table 1: Application interface combinations

CONDITIONS		Zoom	
		Physical Device Proximity	Finger Pinch Manipulation
Rotation	Physical Device Orientation	None	Pinch
	Finger Glide Manipulation	Touch	Both

2 Design and Implementation

Are there quantitative or qualitative advantages of using one manipulation metaphor technique or combination of manipulation metaphor techniques for interface interaction of a 3D Augmented Reality application? We analyzed the techniques with regard to accuracy, task completion time, and user preference. We hypothesized that non-mixed interfaces, physical zoom paired with physical rotation and pinch zoom paired with touch rotation, would perform the best. We believed the mixed pairings would be counterintuitive since the metaphors work in different frames, normal physical interactions versus touch screen interactions. When individually assessing the techniques, we assumed users would prefer the swipe rotation and pinch zoom due to the prevalence of these interactions in devices and the fatigue from using physical manipulations.

Our AR application for viewing 3D models was developed in Unity with the Qualcomm Vuforia AR toolkit. An Asus Infinity Pad was used along with printed frame marker cards, mapped to display one of thirty 3D cultural artifact models. The models are replicas of artifacts from the Victoria and Albert Museum, London developed by the 3D-COFORM project. The only identifying aspects on the frame marker cards were the printed 2D text, the title, time period, place of origin of the artifact, and assigned ID number.

The four techniques include physical zoom, pinch zoom, physical rotation, and finger swipe rotation. For physical zoom, the user physically alters the distance between the tablet and frame marker. The two-finger pinch zoom uses two fingers for the traditional outward pull for magnification or inward closure for shrinking. For physical rotation, the user moves the device or rotates the frame marker. The single finger touch rotation allows any directional finger swipe starting on the object. These were mixed to create four interfaces with zoom and rotation capabilities. The combinations and names can be seen in Table 1. Each participant completed tasks with all four interfaces. The tasks involved inspection of the 3D artifacts and were varied by counting, search and find, comparison, and detail processing/interpretation task type categories.

3 User Study & Results

For the within-subjects user study, interface order was counterbalanced. Users had a demo and answered eight questions, two of each task type for each interface with a set of new frame markers. They filled out a survey after each interface and a final survey at the end. A total of 22 student users of seven different nationalities participated, 3 female and 19 male. Ages ranged from 19 to 35 averaging 22.5. All had gaming experience and 19 of 22 had very little to no Virtual Environments or AR experience.

Accuracy For accuracy, user responses were analyzed for correct details and relevance. None and Both outperformed the Pinch and Touch interfaces in all tasks except the Comparison. An ANOVA analysis was done and a Levenes test resulted in an F-value of 26.972 ($p < 0.0001$). There was a significant difference between both interfaces and task types. A significant interface effect ($F = 6.254, p < 0.0001$) was found. A significant task effect with an F-value of 17.046 ($p < 0.0001$) indicated a difference between the task types. For the Counting, Search, and Interpretation tasks, there are significant interaction effects among the interfaces.

Speed Taking the mean times for all task types per interface, the interfaces with the fastest and slowest completion times were the None and Pinch, respectively. An ANOVA analysis was done and a Levene's test produced an F-value of 7.718 ($p < 0.0001$), showing a significant difference between the interfaces and between the task types. The interaction effect shows an F-value of 13.66 ($p < 0.0001$) indicating a significant interaction effect of interfaces and task type on task time. A significant interface effect ($F = 19.201, p < 0.0001$) was also found. A significant task effect for time was also found with an F-value of 74.737 ($p < 0.0001$). A Tukey post-hoc test indicated that every pairwise comparison for every task type was statistically significant with all p values < 0.05.

User Preference Participants rated each interface for ease of use and intuitiveness based on a Likert scale with 7 being the highest. The rankings for ease of use were None (5.09), Touch (5.00), Both (4.73), and Pinch (4.59). For intuitiveness, the rankings were None (6.23), Touch (5.00), Both (5.00), and Pinch (4.73). Participants also rated each isolated technique per interface. The Touch interface techniques were highest rated for ease of use, although the touch rotation for this interface was one of the two lowest rated for intuitiveness. The Both interface techniques were rated lowest for ease of use and intuitiveness, along with the Pinch interface pinch zoom and the Touch interface touch rotation. The None interface techniques had the overall highest average ratings for intuitiveness. Users also gave their favorite interface and individual manipulation techniques. The favorite interface was tied at 32% for the Both and Touch interfaces with the Pinch and None interfaces tying at 18%. For rotation, the touch rotation came first at 59% with 36% preferring the physical and 5% having no preference. The physical and pinch zoom techniques tied at 41% with 18% having no preference.

4 Discussion

Both of the non-mixed metaphor interfaces outshined the mixed metaphor interfaces in the categories of accuracy, speed, and intuitiveness. A summary of the interface rankings and attribute findings can be seen in Table 2. The non-mixed metaphor interfaces were shown to outperform the mixed metaphor interfaces in the areas of speed and accuracy. In fact, the None interface, or physical zoom and physical rotation combination, had the fastest average completion times and the Both interface had the overall fastest completion time for a task. For task performance, the Both interface had the highest percentages of correct answers across all task types followed closely by the None interface, which tied the Both interface in every task type except the Counting task.

The category for user preference had the None, non-mixed metaphor interface, as the highest ranking interface for both ease of use and intuitiveness. Further, the None interface was noted by many participants as being the most natural and leading to a more immersive experience. The two favorite interfaces were a non-mixed and a mixed metaphor interface, the Both and Touch. Overall, the users preferred the finger touch rotational technique over the physical rotation while the pinch zoom and physical zoom techniques were tied. This supported why the user preferred interface was a tie between the Both and Touch. These interfaces included the favorite rotational technique paired with both the pinch zoom and physical zoom techniques respectively.

Table 2: Interface Rankings and Attributes

Interface	Interface Type	Techniques	Accuracy Ranking	Speed Ranking	Ease of Use Ranking	Intuitiveness Ranking	Favorite Interface	Favorite Rotation	Favorite Zoom
Both	Non-mixed	Pinch Zoom Touch Rotation	1	2	3	2	Tied	Yes	Tied
None	Non-mixed	Physical Zoom Physical Rotation	2	1	1	1			Tied
Pinch	Mixed	Pinch Zoom Physical Rotation	3	4	4	3			Tied
Touch	Mixed	Physical Zoom Touch Rotation	4	3	2	4	Tied	Yes	Tied

5 Conclusions and Future Work

The results and analysis of this cultural heritage application of an AR interface revealed many insights related to task completion time, accuracy, and user preference. There were rich and significant relationships between these interfaces and users' objective performance and subjective ratings. In general, these support the notion that 3DUI metaphors should not be mixed in AR manipulation techniques. However, users rated the mixed Touch interface high for ease of use and as a favorite, suggesting a level of engagement that might offset raw performance advantages. Our results are applicable to 3D user interface manipulation techniques in AR applications and in the broader fields of human computer interaction, augmented reality, and virtual environments. As we continue to use tablet devices and develop new technologies for user manipulation and 3D modeling, further study into metaphors will be required in order to enable positive user experiences and enhanced performance in terms of speed, accuracy, and other measures.

Acknowledgements

For their efforts and contributions, we acknowledge the following: Siroberto Scerbo (VT), Doug Epps (VT Sign Shop), the Victoria and Albert Museum, London, and the 3D-COFORM project.

References

[1] S. Burigat, L. Chittaro, and S. Gabrielli. Navigation techniques for small-screen devices: An evaluation on maps and web pages. *International Journal of Human-Computer Studies*, 66(2):78–97, 2008.

[2] C. Gutwin and C. Fedak. Interacting with big interfaces on small screens: a comparison of fisheye, zoom, and panning techniques. In *Proceedings of Graphics Interface 2004*, page 145152, 2004.

[3] R. J. K. Jacob, L. E. Sibert, D. C. McFarlane, and M. P. Mullen. Integrality and separability of input devices. *ACM Transactions on Computer-Human Interaction*, 1(1):3–26, 1994.

[4] F. Kawsar, E. Rukzio, and G. Kortuem. An explorative comparison of magic lens and personal projection for interacting with smart objects. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services - MobileHCI 10*, 2010.

[5] A. Martinet, G. Casiez, and L. Grison. Integrality and separability of multitouch interaction techniques in 3d manipulation tasks. *IEEE transactions on visualization and computer graphics*, 18(3):369380, 2012.

[6] A. Morrison, A. Oulasvirta, P. Peltonen, S. Lemmel, G. Jacucci, G. Reitmayr, J. Nsnen, and et al. Like bees around the hive : A comparative study of a mobile augmented reality map. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1889–1898, 2009.