Investigation of Interaction Modalities Designed for Immersive Visualizations Using Commodity Devices in the Classroom

Kira Lawrence[1], Alisa Maas[2], Neera Pradhan[1], Treschiel Ford[3], Jacqueline Shinker[1], and Amy Ulinski Banic[1]

[1] University of Wyoming, Dept. 3315, 1000 E. University Ave, Laramie WY, 82071
[2] Wheaton College, 501 College Ave Wheaton, IL 60187
[3] Alabama A&M University, 4900 Meridian Street North, Huntsville, AL 35810-1015
{klawren2,jshinker,abanic}@uwyo.edu, npradhan0603@gmail.com, Alisa.Maas@my.wheaton.edu, treschielford@live.com

Abstract. In this paper we present initial research of the investigation in the design collaborative interaction modalities for classroom-based immersive visualizations of 3D spatial data, with an initial implementation for geo-spatial applications. Additionally we allowed some pilot testing to gain a sense of our design decisions and where user error might occur. Valuable feedback will allow us to redesign and refine implementation for a much more formal long-term evaluation of the system. Initial results give indications that our interaction modalities may facilitate teaching and learning, but the use of devices should be different for user type.

Keywords: Immersive Visualization, 3D User Interfaces, Collaborative Interaction, Classroom, Geospatial data, and GeoWALL.

1 Introduction and Motivation

The field of Visualization was described as transferring the symbolic into the geometric, enabling researchers to observe their simulations and computations [6]. The goal of visualization is to leverage existing scientific methods by providing new scientific insight through visual methods. Visualizations have been and are continuing to be developed for many different fields and purposes, such as medical research and procedure assistance, biological research, physical sciences, engineering, geosciences, security, business, and education. For education purposes, visualizations offer insight, many visualization applications are being used for discovery and learning in the classroom. Additionally, it has been shown that immersive visualizations provide facilitate discovery and allow for better workflow [8,10]. Immersive 3D visualization has been promoted by geoscientists to understand the physical world because of its positive impact on understanding the phenomenon for geoscientists as well as any novice user with minimal information [12]. One example of an immersive visualization for educational purposes is the use of a GeoWall, a large polarization-based passive, or not

A. Marcus (Ed.): DUXU/HCII 2013, Part II, LNCS 8013, pp. 209–218, 2013.

head-tracked, dual projector-based stereoscopic or immersive display, for the purposed of teaching geographical concepts, with interactivity of real-time data exploration being a crucial aspect [5]. A Geowall is a stereoscopic display system built by collaboration between computer science and geoscience to help in understanding the spatial relationships in the study of earth sciences.

One possible issue with this system is that there are particular limitations in interaction with this display. Typically these systems are used by one user, usually the instructor. This creates a problem if the instructor wishes to allow the students to explore the visualizations for themselves rather than driven by the instructor. The other issue is that some devices and interaction may cause reduced usage due to the complexity of 3D interaction. As a result more investigation is needed for solving similar collaboration issues in interaction. Additionally, once allowing for collaboration in interaction, other issues present themselves, such as cost of multiple devices, interaction techniques that facilitate collaboration, how to mitigate turn taking or should simultaneous interaction be permitted. Several researches have shown that similar immersive display technologies are better utilized depending on interaction techniques [7, 14]. Also, according to the NIH/NSF visualization research challenges report in 2006, designing effective visualizations is a complex process that requires a sophisticated understanding of human information processing capabilities, outlining interaction as one of the main areas where visualization research needs to focus [6]. There is a need then for the development and evaluation of general interaction techniques that can be applied to broader categories of visualization applications. In this research, we will focus mainly on collaborative interaction for scientific visualizations, using climate visualizations as a test case, for classroom usage. In this paper, we propose initial designs of interaction modalities, such as multiple views, independent navigation and selection tasks, and multiple cursors, for the use of immersive visualizations in learning environments such as learning geo-spatial concepts on the GeoWall. We additionally present some insights gathered while pilot testing our initial prototype implementation.

2 Background and Related Work

2.1 GeoWall

In 2001, the GeoWall project found that the building GeoWalls in university classrooms aided introductory students with understanding new concepts [5]. Students displayed 3D immersive models both in class and for projects. The GeoWalls were also found to be incredibly helpful for demonstrating complex processes to the general public. A GeoWall is comprised of a large silver screen that faces two projectors. The projectors are aligned so that both images pass through a polarized filter and then overlap on the screen. This filtering matches polarized glasses to filter out images from either the right or left eye, similar to the passive, stereoscopic setup used in commercial movies and amusement park attractions.

Fig. 1. a) View of GeoWall configuration at WyGISC at the University of Wyoming. b) View of students wearing polarized glasses in the classroom to be able to see the images on GeoWall.

2.2 3D Input

GeoWall has been proven successful at other universities and has proven itself an important tool for viewing 3D data [5], and there have been an extensive number of studies done on suitable input devices for 3D environments [1, 9, 15, 16]. Devices with six degrees of freedom such as 3D mice, wands, and gloves have been tested in a variety of computer applications for their ability to navigate and manipulate a 3D scene. However, no single device has been shown to be superior for 3D applications[3]. Considering low-cost robust options for our system, we investigated a Nintendo Wii Remote as input devices for classroom use with the immersive display. Nintendo Wii Remote, or Wiimote, is one input device that has been growing in popularity to be used. Wii Remotes have been implemented as computer mice before [13]. Additionally they have been studied by many as input for interaction with 3D and immersive environments [4, 9, 13, 15]. Research showed that using Wiimote as a mouse to operate is viable approach and supports multiple interactions. It is cheap, affordable and offers as reliable hardware for input interaction. Other research has shown that 2D devices can perform adequately in a 3D environment when using them with a limited scope of options and navigation [11].

3 System Framework

For our system, we chose a Nintendo Wii Remote as our input device. We used the remote as a 2D mouse, with button-mapped tasks that were specific for use in ArcScene. Furthermore, 3D tasks could be mapped to the accerometer input from the device. Our implementation utilized both the Wii Remote and the Nunchuk as a single asymmetric bimanual device. Since we wanted interaction to be able to be utilized in a standard way across multiple applications, we used an input emulator rather than handling all of the Wii Remote events directly. By using an emulator, we could easily adapt our existing code for more applications, allowing more departments to use our interface within their programs with little to no consultation.

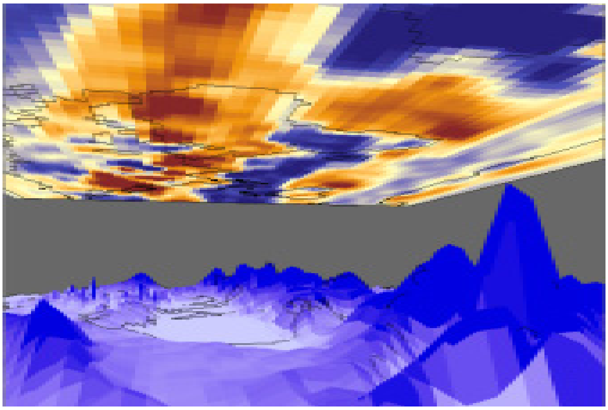

Fig. 2. An example view of visualization of 3D geo-spatial data

3.1 Software

The GeoWall at the University of Wyoming makes use of ArcGIS Desktop 10.0 geographical information software to view the data. In particular, our case study focused on the use of ArcScene, since it is capable of creating and processing 3D visualization data and was used heavily in one of the classes for visualization examples, where in the future we could likely conduct an evaluation in this type of class.

ArcScene is a program that is heavily dependent on mouse input. We decided to use the Nunchuk joystick to control the cursor rather than the Wii Remote's motion sensing capabilities, and rather reserve that for other tasks. This made the implementation similar to the mouse and cursor setup that faculty would be accustomed to while optimizing the button layout for the program. By using the joystick, we also eliminated the repetitive wrist movements from constantly clicking and dragging an object in ArcScene, and can cause discomfort and fatigue.

3.2 Input Devices

Selecting a suitable input device was an important factor in this project because it needed to be robust, flexible, cheap, and duplicable for use in the classroom setting. It was also critical that our device was both as accessible to faculty as possible while still functioning within ArcScene. We took the environment in consideration as well, examining the range, portability, and extensibility the device had for multiple users. Based on these criteria, we determined that a gesture recognition device, such as a Kinect, may not have been the best solution for this particular case study. In a classroom setting where number of students can be large and only a limited open space may be available within the classroom, gesture recognition may become less accurate as we engage multiple students to interact. Such a device requires exaggerated body movements from the user, and becomes tiring after long periods of use. Since typical classroom usage could require anywhere from fifty minutes to two and a half hours, we determined this type of device would be unsuitable for this purpose. In some cases, a device of this nature may require the user to be interacting in a limited line-of-sight range directly in front of it. Also, a user may unconsciously gesture when using the GeoWall, causing the device to read extraneous input and alter the scene without the user's intent. An example is that an instructor may use hand gestures while lecturing which may causes recognition errors or require mechanisms to switch modes. Also, since we wanted users to use devices efficiently without much training, we found a gesture-based input device problematic in this setting for the following reasons: 1) Users would not be aware of which gestures could be interpreted as commands. 2) Therefore, users would more likely to require extensive training and a manual to understand the controls. This may make the system appear more, not less, complicated.

Another category of input device we investigated but decided it also would not be sufficient for our needs was a standard game controller. A typical device of this category has more buttons and control options than needed for this case study, and appeared complex to novice users based on initial pilot testing. As a result, we believed faculty might feel overwhelmed by this controller and have difficulty remembering where functions were mapped. These issues may increase cognitive load, and therefore decrease insight and learning, which is counterproductive to the purpose of the GeoWall. Ultimately, we selected the Nintendo Wii Remote to serve as the input device for the GeoWall in this context. The Wii Remote had fewer buttons and joysticks, making the setup easier for the users to understand and remember. The Wii Remote does not confine lecturing faculty to specific regions of the classroom, and does not require extreme gestures as input.

Another category we considered were natural user interface based controllers, such as a Nintendo Wii Remote. It is a low cost, easy to use, hand held device that can be used and well-suited for an immersive environment [13]. This device may be more suited for classroom use, because of small localized area of control, intuitiveness, affordability, and flexibility in control. However, a Wiimote sensor was not accurate to use as mouse cursor movements because of its sensitivity and error. For user convenience, we found that Nunchuk works more effective as mouse. Then, we decided to choose Nunchuk to emulate mouse buttons because it was easier to map the cursor movement with joystick and we could do it with more accuracy than with Wiimote sensor movement.

3.3 Input Mapping

We used Glove Programmable Input Emulator (GlovePIE) for mapping button presses and other actions to keyboard keys, mouse input or joystick buttons. A Targus Bluetooth dongle was used to enable a wireless connection between the device and the system to be used throughout the classroom. This Bluetooth device is capable of locating and connecting to up to four Nintendo Wii Remotes at a time. With ArcScene open, an image could be panned up, down, left, and right by pressing the corresponding direction on the Wii Remote's directional pad. Additionally, the accelerometer could be used for more generalized gross changes in orientation, while the buttons could be used for more precise navigation.

Initially, we implemented the mapping for Wiimote buttons A and B as mouse left and right click respectively. However, we decided this setup was unintuitive after several pilot trials and user feedback. As a result, we then mapped Nunchuk Z and C as mouse left click and right click respectively, as it is convenient for users to have mouse click buttons on the same device. The plus and minus buttons on either side of the remote changed cursor sensitivity, while the "A" button re-centered, resized, and repositioned the scene back to its default view. The "Home" button in the center of the Wii Remote created two new window views of the scene. The new viewers were quickly set to stereo display, sized, and positioned across both monitors so that the screen holds two separate 3D views of an image that can be manipulated separately. The following provides an overview of the subset of commands in ArcScene that were implemented with Wiimote buttons:

Wiimote A	*= reset image*
Nunchuk C + Nunchuk Joystick	*= zooming*
Nunchuk Z + Nunchuk Joystick	*= rotation*
Wiimote Home	*= setting window viewers*
Wiimote 1	*= Exit Program*
Wiimote DPad	*= panning (Single Wiimote)*
Nunchuk Joystick	*= mouse*

When doing pilot testing, we did not discuss the mappings, but rather let the user investigate and learn the tasks in relation to the performed action.

Fig. 3. Image of user with input device while interacting with multiple views of the immersive visualization

4 Collaborative Interaction

Our goal was to facilitate collaborative interaction with a GeoWall for the classroom use. We first needed to address the need for multiple camera projections of the same data to facilitate independent exploration. We therefore designed and implemented our interaction techniques to activate multiple windows in ArcScence with Wiimote Home button. We made use of Desktop's multiple viewers to make this possible.

We set up the Home button on the Wii Remote to open two viewers, position and size them ideally for 3D, and set the viewing mode in stereo. This way the instructor would be capable of opening and positioning the viewers for multiple students instantly, rather than being required to manually set them up. Our intention is doing this is to provide the instructor with a way of involving the students more directly in the learning process.

Next, we needed to address the problem of users' input competiting for mouse pointer usage, where in these applications many of the tasks were dependent on. GlovePIE makes it possible to add FakeCursors, which look and behave, for the most part, like regular cursors. Using Glovepie, we created an imitation cursor that can move and work independent of the real cursor. As a result, multiple windows using two Wiimotes could be interactively updated simultaneously. With multiple cursors and windows, instructors can interact in a window to explain one concept while a group of students can interact with another window freely to explore the visualization, with the potential of "just-in-time" active learning. There were no conflicts between two Wiimotes for any button press except for panning. For some reason, panning did not work as smooth as with the mouse and the images appear to flicker and sometimes disappear from the screen. Our reasoning behind this was that input from multiple cursors was taken into account and the ArcScene used both inputs to get the median value to position the graphics which caused a few registration errors. Another challenge was that since the software was not equipped to manage multiple sources of input at once, some functionality had to be removed from the second user. We intended the secondary capabilities to be used with the instructor as primary controller, while students had a sub-set of actions they could perform, though sufficient for exploration.

5 Initial Pilot Testing

In pilot testing, we asked several instructors and students involved with the project to try out our interaction modalities: three instructors and six students provided feedback. For instructors, we wanted to gauge the usability of the system we created. We adapted questions from the System Usability Scale (SUS) and tailored them to fit with our system characteristics [2]. As they used the system, we allowed participants in the evaluation to hold the Wii Remote in any hand they were comfortable with. We noticed those familiar with the Wii Remote tended to hold the Nunchuk in the non-dominant hand, as is typical in Wii games; and those unfamiliar with the console preferred to hold the Nunchuk in the dominant hand. We provided participants with a sheet that provided the information for what each button did. After the participants were comfortable for using buttons, we gave them break 5 to 10 minutes. Then, we brought them back into Geowall room to explore use of interaction modalities without the information sheet. When they felt they had used all the buttons possible, we asked them to fill out a post evaluation form. We also conducted an open interview with them to get more detailed answers to word questions. Responses to each statement were given on a likert-type scale of one to seven, with one indicating strong disagreement, and seven indicating strong agreement. Four was a neutral response. These responses were then categorized and averaged across respondents to obtain a rating for each usability criterion.

Table 1. Pilot Testing Results on subjective rating scales from 1 to 7, with higher ratings reflecting a more positive response

	Instructors	**Students**
Efficiency	4.00+/-0.82	4.05+/-1.36
Ease of Use	3.82+/-1.85	4.68+/-1.16
Learnability	3.88+/-1.72	3.87+/-1.50
Errors/Problems	6.33+/-0.47	4.25+/-1.79

5.1 Discussion

The initial results from instructors' feedback are presented in Table 1. Instructor ratings were much lower than we had expected. We believe the instructor scores were lower for several reasons. 1) 2 out of the 3 faculty member participants had never seen a Wii Remote before. Therefore, they were unfamiliar where the buttons were located. Instructors had difficulty understanding and remembering where the buttons were located. This would lead to lower scores in Ease of Use, Learnability, and User Comfort. 2) Due to time constraints, we were only able to find 3 faculty participants, meaning the scores are not a good representation of other faculty members. 3) Also at times there was some interference with Bluetooth, so as a result we may need to implement a more robust solution for the connectivity. Overall, we were able to conclude that efficiency, ease of use, comfort, and learnability scores were neutral for instructors. Instructors thought the use of multiple views and control for the students were a good idea, so as to describe concepts while the students could see multiple aspects of the visualization at one time. Geo-spatial concepts could particularly benefit from this type of exploration since not all components when explaining a particular concept can be seen in one static view.

The initial results from students' feedback are presented in Table 1. We found higher results of usability for students. We believe that results for ease of use, learnability and user comfort were higher due to familiarity with Wiimotes. Students welcomed the idea of not only using 3D visualizations on this type of display more often, but thought the idea of having additional control over what they were seeing could be beneficial for learning. However, there was some concern over if they would need to take turns with other groups.

6 Conclusion

In conclusion, we present initial research in the investigation of collaborative interaction modalities for classroom-based immersive visualizations of 3D spatial data, with an initial implementation for geo-spatial applications. Additionally we allowed some pilot testing to gain a sense of our design decisions and where user error might occur.

Valuable feedback will allow us to redesign and refine implementation for a much more formal long-term evaluation of the system. In conclusion, faculty had difficulty with the devices, but valued the interaction capabilities for multiple users. Students have less difficulty, possibly due to familiarity with the system. Students also were concerned about having to take turns to control the visualization. Use of the Wiimote facilitates students' engagement but lead to frustration for instructors, so there is a possibility of using focused devices for the user type.

7 Future Work

An immediate step would be to revise the interaction mappings according to the feedback provided, such as adjustments to zooming and panning. Additionally, we shall refine the collaborative techniques and conduct a long term user study with actual usage in a classroom that typically utilizes these types of visualizations in an immersive environment. Since the Bluetooth used only supports up to four input devices and the visual display is limited in the number of separate views we can provide, we will investigate groups of student users. Also, we could compare with other input devices in order to provide a usability benchmark. We can evaluate whether any enhanced learning occurs as the result of our interaction system. Long term we plan to investigate interaction techniques and other hardware solutions which will allow multi-user collaboration without multiple divided views.

Acknowledgements. This work was supported in part by, the CRA-W Distributed Research Experiences for Undergraduates (DREU) and the University of Wyoming EPSCoR Research Experiences for Undergraduates (REU) programs. Also, a special thanks to the University of Wyoming Geographic Information Science Center (WyGISC) for permitting usage of their GeoWall facility and providing valuable initial feedback on our system.

References

1. Ardito, C., Buono, P., Costabile, M.F., Lanzilotti, R., Simeone, A.L.: Comparing low cost input devices for interacting with 3D Virtual Environments. In: 2nd Conference on Human System Interactions, HSI 2009., May 21-23, pp. 292–297 (2009)
2. Brooke, J.: SUS: a "quick and dirty" usability scale. In: Jordan, P.W., Thomas, B., Weerdmeester, B.A., McClelland, A.L. (eds.) Usability Evaluation in Industry. Taylor and Francis, London (1996)
3. Frohlich, B., Hochstrate, J., Kulik, A., Huckauf, A.: On 3D input devices. IEEE Computer Graphics and Applications 26(2), 15–19 (2006)
4. Gallo, L., Ciampi, M.: Wii Remote-enhanced Hand-Computer interaction for 3D medical image analysis. In: 2009 International Conference on the Current Trends in Information Technology (CTIT), December 15-16, pp. 1–6 (2009)
5. Johnson, A., Leigh, J., Morin, P., Van Keken, P.: Geowall: Stereoscopic Visualization for Geoscience Research and Education. IEEE Computer Graphics and Applications 26(6), 10–14 (2006)

6. Johnson, C., Moorhead, R., Munzner, T., Pfister, H., Rheingans, P., Yoo, T.S.: NIH/NSF Visualization Research Challenges Report. IEEE Press (2006)
7. Marcio, S., Pinho, D.A.: Bowman, and Carla M.D.S. Freitas. 2002. Cooperative object manipulation in immersive virtual environments: framework and techniques. In: Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST 2002), pp. 171–178. ACM, New York (2002)
8. Prabhat, A.F., Katzourin, M., Wharton, K., Slater, M.: A Comparative Study of Desktop, Fishtank, and Cave Systems for the Exploration of Volume Rendered Confocal Data Sets. IEEE Transactions on Visualization and Computer Graphics 14(3), 551–563 (2008)
9. Santos, B.S., Prada, B., Ribeiro, H., Dias, P., Silva, S., Ferreira, C.: Wiimote as an Input Device in Google Earth Visualization and Navigation: A User Study Comparing Two Alternatives. In: 2010 14th International Conference on Information Visualisation (IV), July 26-29, pp. 473–478 (2010)
10. Sherman, W.R., O'Leary, P., Kreylos, O., Brady, R.: IEEE Visualization 2008 Conference Workshop on Scientific Workflow with Immersive Interfaces for Visualization, Columbus, OH, October 19-24 (2008); DVD
11. Teather, R.J., Stuerzlinger, W.: Assessing the Effects of Orientation and Device on 3D Positioning. In: IEEE Virtual Reality Conference, VR 2008, March 8-12, pp. 293–294 (2008)
12. Terrington, R., Napier, B., Howard, A., Ford, J., Hatton, W.: Why 3D? The Need for Solution Based Modeling in a National Geoscience Organization, May 7. AIP Conference Proceedings (serial online), vol. 1009(1), pp. 103–112 (2008)
13. Yang, Y., Li, L.: Turn a Nintendo Wiimote into a Handheld Computer Mouse. IEEE Potentials 30(1), 12–16 (2011)
14. Kitamura, Y., Konishi, T., Yamamoto, S., Kishino, F.: Interactive stereoscopic display for three or more users. In: Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques (SIGGRAPH 2001), pp. 231–240. ACM, New York (2001)
15. Wingrave, C.A., Williamson, B., Varcholik, P.D., Rose, J., Miller, A., Charbonneau, E., Bott, J., LaViola Jr., J.J.: The Wiimote and Beyond: Spatially Convenient Devices for 3D User Interfaces. IEEE Computer Graphics and Applications 30(2), 71–85 (2010)
16. Zhang, S., Overholt, M., Gerard, J., Striegel, A.: WiiDoRF: Decision and recording framework for educational labs centered on the Nintendo Wiimote. In: 2010 IEEE Frontiers in Education Conference (FIE), October 27-30, pp. S1F-1–S1F-6 (2010)