Navigating a Maze with Balance Board and Wiimote

Wim Fikkert, Niek Hoeijmakers, Paul van der Vet, and Anton Nijholt

Human Media Interaction, University of Twente
P.O. Box 217, 7500 AE, Enschede, The Netherlands
{f.w.fikkert,n.j.hoeijmakers,p.e.vandervet,a.nijholt}@utwente.nl

Abstract. Input from the lower body in human-computer interfaces can be beneficial, enjoyable and even entertaining when users are expected to perform tasks simultaneously. Users can navigate a virtual (game) world or even an (empirical) dataset while having their hands free to issue commands. We compared the Wii Balance Board to a hand-held Wiimote for navigating a maze and found that users completed this task slower with the Balance Board. However, the Balance Board was considered more intuitive, easy to learn and 'much fun'.

Keywords: H.5.2. User interfaces, Evaluation, Input devices and strategies.

1 Introduction

New forms of interaction keep flooding the market, introducing engaging and often unexpected new experiences to the public. Hand and other bodily movements now serve as input for game consoles. Similarly, input from the lower body in human-computer interfaces can benefit the interaction by enabling natural proprioception. In addition, users have their hands free to perform other, simultaneous tasks such as issuing commands to a virtual game world (World of Warcraft, Killzone) that they are navigating through with their lower body [1]. Such an interface has the potential to be more enjoyable because users can divide attention between tasks. In addition, lower body input can be highly entertaining, even enticing users to start interacting. This is, for example, illustrated by the Wii Fit game that is enthusiastically used in elderly homes for entertainment and in medical centers for rehabilitation[1].

Our contribution is an evaluation of the performance and, more importantly, enjoyability of users navigating a virtual maze world with their lower body while they are performing cognitive tasks with a hand-held device [2]. Section 2 describes related work on lower body HCI and ways to evaluate such interactions. In Sect. 3 we describe our evaluation of combining the Nintendo Wiimote and Balance Board for navigating through a simple maze. Sections 4 and 5 present the results and conclusions of this evaluation respectively.

2 Related Work

2.1 Lower Body Input

Navigating virtual worlds through virtual walking, where the user can physically walk freely through an entire world, has been addressed extensively in systems that fully

[1] In USA today, "Wii finds home in retirement communities, medical centers", on 2008-05-14.

A. Nijholt, D. Reidsma, and H. Hondorp (Eds.): INTETAIN 2009, LNICST 9, pp. 187–192, 2009.

immerse their users. The VirtuSphere[2] enables virtual walking by placing its users inside a large sphere in which they can walk, run, roll and even jump. See Kruijf's PhD thesis for a more extensive overview [3]. Interfaces that do not completely immerse their users typically require them to remain stationary for large displays or use users' mobility in portable interfaces. The JoyFoot uses accelerometers to detect ankle movements for controlling navigation in a virtual world [4]. The JoyFoot was evaluated with a large display in a game setting where users had to navigate an asteroid debris field game world in two dimensions by moving their feet on the floor. Reidsma et al. [5] presented their virtual dancer where users were enticed to engage in a dancing dialogue with a virtual dancer. A game dance mat[3] is used to detect the user's presence while a crude computer vision solution is used to detect dancing motions. Map manipulation has also been shown to benefit from combining a touch-sensitive wall-sized display for selection and activation with lower-body input from a Wii Balance Board for navigation [1]. It has also been suggested that the Balance Board can be a useful modality to perform 1 DOF control tasks by the feet [6].

2.2 Evaluating Input Devices

Input devices can be thoroughly evaluated on task completion times, error rates and user satisfaction on various tasks using the ISO 9241-9 standard [7] which is based on Fitts' Law on human motor control. The standard defines performance measures for evaluating input devices or techniques using basic interfaces tasks such as tap, drag and trace. Like [1], we are interested to explore the effect of tracing complex paths, for example, as found in map navigation. This goes beyond the underlying assumptions in Fitts' Law that eliminates the cognitive aspects of an interaction as much as possible in an effort to focus on the motor abilities of humans.

3 Methodology

Our large display interface, see Fig. 1, combines lower-body input (from a Wii Balance Board) with input from the hands (from a Wiimote). Users performed a time-crucial navigation task in a set of simple mazes during which they were required to input commands manually. These commands were issued at set locations in the maze, without which the user could not continue. The user controlled an avatar (green dot) in our maze task. Subjects in this study were selected based on sufficient computer experience. We hypothesize that the the Balance Board will be more intuitive for simultaneously navigating and issuing commands while not suffering loss in performance.

3.1 Devices for Navigating the Maze

The Nintendo Wiimote and Nintendo Balance Board were used in a within-subjects evaluation, see Fig. 1. The Wiimote has three perpendicular accelerometers and an IR

[2] Available online at `http://www.virtusphere.com/`, last checked feb. 2009.

[3] Dance Dance Revolution: `http://www.konami.com/ddr/`, last checked feb. 2009.

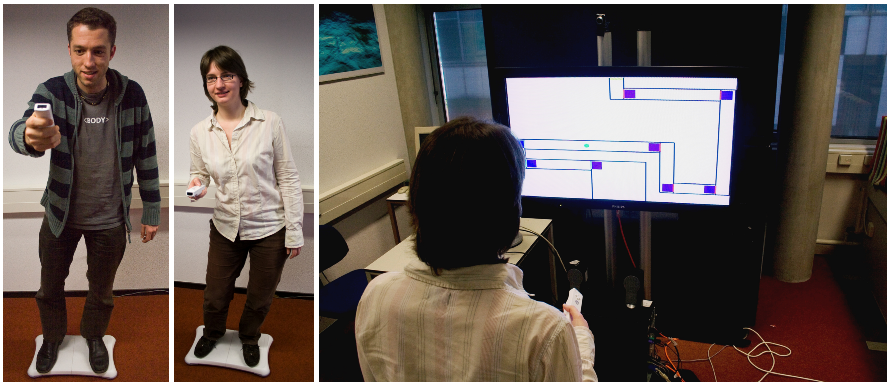


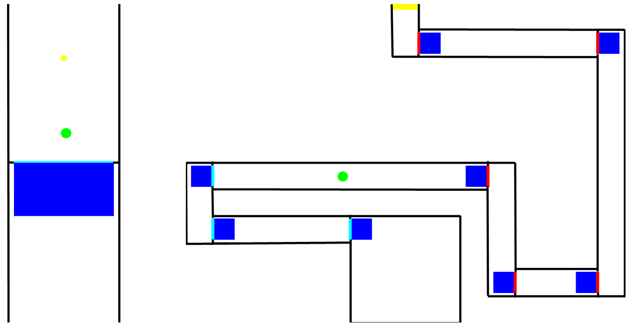
Fig. 1. The maze navigation task combines the input from a Balance Board and Wiimote alike. Subjects enjoyed both navigation approaches; using either the Wiimote or Balance Board. While navigating, users were required to press buttons on the Wiimote in order to complete the maze.

camera that detects fixed light sources for absolute pointing. The Balance Board (or board for short) has four pressure sensors at each of its corners.

Our test subjects completed two scenarios in counterbalanced order. The first scenario (BW) combined the board with a single Wiimote. In BW, the board was used for navigation; the subject stands on the board and shifts his center of gravity to move the avatar. Leaning forward moved the avatar up, left moved it left and so on. This is very similar to how a Segway works. The Wiimote could be held in the preferred hand (either left or right) and on set positions in the maze the subject was required to issue an command with it, see Sect. 3.2. In the second scenario (WM) our subjects only used one Wiimote to control both the avatar and issue the commands in the maze. A similar form of navigating the maze with the Wiimote was selected compared to BW; the accelerometers were used to detect roll (for moving left and right) and pitch (for moving up and down). We specifically chose not to use the embedded IR camera for detecting pointing (see [2]) because it could bias the avatar's movement speed. The avatar top movement speed was equal for BW and WM, matching the maximum pitch or lean.

3.2 The Maze Task

Subjects in our study navigated four mazes, seen from above, of varying difficulty, see Fig. 2. The four mazes were presented in the same order for both of the above scenarios. Before starting the first maze, our subjects were allowed a brief training session to get used to the device for navigation and to learn how to issue commands with the Wiimote. Each maze consisted out of a sequence of rooms that were connected by doors, ending with a maze exit. The subject had to navigate/walk to a each (closed) door and, while standing in front of the door on a doormat, press a button to open the door. The button to press was displayed on-screen only when a subject was standing on a doormat. After a correct button-press, the door would open so that the subject could proceed to the next room. Pressing an incorrect button would give a visual error signal.



(a) (b)

Fig. 2. The set of mazes consisted out of very simple (a) linear paths to (b) more complex paths. Maze components were identified by their color. In all cases, only one path existed.

3.3 User Evaluation

A paired t-test was used to compare our two scenarios (BW and WM) to each other. For each maze we measured the task completion time in addition to the time that a user stood still on a doormat as measure for performance. As a measure for error rate, we counted impacts with the walls of the maze and closed doors in addition to incorrectly entered commands. User personal data was gathered to assess their previous experience with the devices in this experiment or similar input devices. After completing each scenario, the user filled out a questionnaire in which they rated the interaction. Upon completing both scenarios the users rated which device they enjoyed the most for navigating.

4 Results

18 subjects participated in our evaluation, 4 female and 14 male ($\mu = 29$ years, $\sigma = 11$ years, ranging 18 to 56 years). 9 subjects held a Masters degree, 6 a Bachelors and 3 had no degree. On a 1-5 scale, our subjects were proficient with the Wiimote ($\mu = 3.4$, $\sigma = 1.2$) before taking part in the study but the Balance Board ($\mu = 2.3$, $\sigma = .9$) and other motion capture solutions ($\mu = 2.0$, $\sigma = .8$) were less familiar.

With respect to performance, we found that task completion time with WM was significantly faster (17 seconds faster, $p = 0.04$). After the test, most subjects (10 for WM, 4 for BW) also indicated that they experienced WM to be the faster solution for navigation. The number of wall and door hits did not differ significantly between BW and WM, nor did the number of incorrectly issued commands. However, 17 subjects indicated after the test that they experienced WM to be less prone to bumping into walls or doors (1 experienced no difference). We found that our subjects maintained their location on doormats more consistently for WM ($\mu = 4.3$ fewer drifts, $p < 0.01$). The total time spent on doormats did not differ significantly but on average each pass took significantly less time using BW ($\mu = 0.47$ seconds, $p = 0.04$).

We found no significant difference in ease of learning, the intuitiveness of the navigation and smoothness of the navigation between both techniques (BW and WM) for navigation in our user opinions after each scenario. However, in the evaluation after the test most subjects (10) indicated that BW was easiest to learn while 6 subjects found WM easier to learn. Likewise, BW was considered the most intuitive (13 subjects, 2 for WM). Our subjects rated the navigation accuracy significantly higher in favor of WM ($p < 0.01$) after each scenario and in the evaluation after the test (12 subjects, 2 for BW). Although we did not find a significant difference for opening the doors between BW and WM, five subjects indicated that they were not familiar enough with the Wiimote to find the required button right away. Although there was no significant difference in the extent that our subjects enjoyed using either WM or BW, they indicated after the test that BW was the most fun (12 while 2 had more fun with WM).

In observations during our trials we noticed that most subjects navigated in only one direction with WM at any one time. For example, a subject would move up first and then turn left rather than moving in both directions simultaneously. Similarly, we observed that our subjects would in most cases complete the navigation task first. Only after ensuring that they remained stationary on a doormat would they focus on opening the door. During the trials four subjects commented that they found our implementation for moving up and down with WM counter intuitive. They would rather invert it so that pitch down moves the avatar forward, arguing that that would be exactly the same as the BW implementation.

5 Conclusions and Future Work

By using the lower body to navigate a virtual world users keep their hands free to complete to perform other tasks simultaneously such as issuing commands. We have compared the Wii Balance Board to a hand-held Wiimote for navigating a series of simple mazes. While navigating the maze of consecutive rooms, our users had to open doors between these rooms on set locations directly in front of the doors. Users could navigate with the board by shifting their center of gravity through leaning or by changing the roll and pitch of the Wiimote in their preferred hand.

We hypothesized that the Balance Board would be more intuitive for the navigation task while not suffering a performance loss. Although we found that the board was easier to learn and use, the Wiimote was significantly faster in navigating the maze without resulting in an increase in navigation errors or errors in the issued commands. This suggests that using the same input modality (a hand-held device) performs better for navigating a virtual world while simultaneously issuing commands. However, we argue that the fun-factor of an interface is equally or even more important for many applications, especially games. Our subjects strongly indicated that they enjoyed using the combination of Wiimote and the Balance Board more, although it was not faster to complete the game. This raises a good point in that novelty is a very important factor for perceived the fun-factor. We expect that a comparison between Wiimote and joystick would provide similar differences. An unbiased assessment would require the users to become much more proficient with both devices.

Some subjects wanted to invert the pitch for navigating to match Balance Board navigation; leaning forward would move the avatar forward. We chose not to implement that approach in favor of mimicking ray-casting to the screen where pointing to the bottom of the screen would move the avatar down.

One aspect that we did not investigate was to what extent the lower body is suited to perform navigation as well as issuing the crude commands that we used in our evaluation. When compared with the current results we expect to find an increase in task completion time with a similar error rate. Trajectory analysis can be used to evaluate the distance to the ideal path through the maze. In addition, our observation that subjects moved the avatar along one axis at any one time could be grounded.

Acknowledgements. This work is part of the BioRange program carried out by the Netherlands Bioinformatics Centre, which is supported by a BSIK grant through the Netherlands Genomics Initiative, and the GATE project, funded by the Netherlands Organization for Scientific Research (NWO) and the Netherlands ICT Research and Innovation Authority (ICT Regie).

References

1. Schöning, J., Krüger, A.: Multi-modal navigation through spatial information. In: Cova, T.J., Miller, H.J., Beard, K., Frank, A.U., Goodchild, M.F. (eds.) GIScience 2008. LNCS, vol. 5266, pp. 151–154. Springer, Heidelberg (2008)
2. Fikkert, W., van der Vet, P., Nijholt, A.: Hand-held device evaluation in gesture interfaces. In: Gesture Workshop 2009 (February 2009)
3. Kruijff, E.: Unconventional 3D User Interfaces for Virtual Environments. PhD thesis, Institute for Computer Graphics and Vision, Graz University of Technology, Graz, Austria (October 2006)
4. Barrera, S., Takahashi, H., Nakajima, M.: Joyfoot's cyber system: a virtual landscape walking interface device for virtual reality applications. In: International Conference on Cyberworlds, pp. 286–292 (2004)
5. Reidsma, D., van Welbergen, H., Poppe, R., Bos, P., Nijholt, A.: Towards bi-directional dancing interaction. In: Harper, R., Rauterberg, M., Combetto, M. (eds.) ICEC 2006. LNCS, vol. 4161, pp. 1–12. Springer, Heidelberg (2006)
6. de Haan, G., Griffith, E., Post, F.: Using the Wii Balance Board™ as a low-cost VR interaction device. In: VRST 2008: Proceedings of the 2008 ACM symposium on Virtual reality software and technology, pp. 289–290. ACM, New York (2008)
7. ISO: Ergonomic requirements for office work with visual display terminals (vdts) - part 9: Requirements for non-keyboard input devices. Technical Report ISO/DIS 9241-9:2000, International Organization for Standardization (2000)