Hands-Free Interaction Techniques for Virtual Environments

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***Abstract*—Techniques that enable user interaction with a Virtual Environment without need of hand-held devices may provide a great potential to increase the degree of virtual presence and, possibly, reduce the distance between the virtual world and the real world. This leads to studies that may enhance user experience in gaming, as well as other areas. This paper presents the implementation and evaluation of several navigation and selection techniques using Microsoft Kinect, through which we strive to allow the user to move and interact with objects in the virtual world in a way similar to how he would in the real physical world. A series of tests were undertaken to evaluate aspects such as ease of use, cognition, time spent to complete tasks, and fluidity of navigation for each proposed technique and the combination of them.**

Keywords—virtual environments; virtual reality; interaction; 3D user interfaces

I. INTRODUCTION

Ever since the 90's we have seen virtual environments (a computer-generated representation of a setting in which the user of the technology perceives themselves to be and within which interaction takes place) establishing themselves as one of the primary platforms for gaming, but for a long time the interaction with them has been majorly through mouse and keyboard combinations. More recently some companies invested in innovative interaction devices, most notably Nintendo Wii®, Sony Move® and Microsoft Kinect®. These devices have enabled advanced and complex forms of interaction, but still far from having an established standard.

In the 3D User Interaction area, defined as the use of human-computer interfaces where the language used to transmit commands and information to the computer and/or the language used by the computer to transmit information to the user are based on the physical world and it's dimensions [1], several studies make use of these technologies in an attempt to increase the naturalness of the users' interaction with the system, reducing cognitive barriers. The idea behind this is to reduce the distance between the virtual world and the physical world using movements similar to what we do on a daily routine [2], which can be defined as "the objective degree of exactness with which real-world experiences and effects are reproduced by a computing system" [3]. This, however, brings some limitations, one of the largest being the restriction imposed by physical space. While a virtual environment may be infinite, our physical space is finite.

The objective of this paper is to present some interaction techniques that have been developed using only corporal movements to perform tasks in a virtual environment and the results of studies with users. Three navigation and three selection techniques have been developed using Microsoft Kinect® as an input device, although they can be used by any system that performs skeleton detection.

This paper is presented the following way: section 2 speaks of related work, section 3 presents the techniques, section 4 presents results and analysis of user tests and section 5 brings the conclusion.

II. RELATED WORK

Related work will be divided into two parts: general interaction techniques and interaction in games for Microsoft Kinect®.

A. General Interaction Techniques

According to Bowman and Hodges [4], interaction in virtual environments is divided into three types: locomotion (navigation), selection and manipulation, where, in many cases, the last two are combined, but can be dissociated. Since in this work both locomotion and selection have been considered, researches about either case have been considered in related work.

All techniques presented in this section have direct relation to the techniques proposed in this paper, either by inspiring a part of a technique or by being a direct basis for the implementation of it's virtual counterpart.

1) Selection

Sibert and Jacob [5] present a selection based on gaze direction. It is based upon a directional ray controlled by the direction of the eyes' gaze, eliminating the need of hand-held devices or devices attached to the user. The selection is triggered when the gaze rests upon an object for a certain amount of time. The idea of relating time to selection intention is contemplated in the *Hover* technique, presented in this paper. Rodrigues et al. [6] studied the advantages of applying multi-touch interface concepts in virtual reality environments by mapping 3D space into a virtual touch screen. To enable this, they proposed a wireless glove which is worn by the user and tracked by a specific configuration of Nintendo WiiMote® controllers. The index finger's position is tracked, mapping the axes into system coordinates. The X and Y axes are used to control the mouse cursor on the screen, while the Z axis is used to determine selection intent by establishing a threshold in the real world as if it were a screen. If the finger passes beyond this threshold the selection is activated and a command is triggered, sending haptic feedback, present in the glove. Even though the glove was designed for and tested in 2D interfaces, it inspired the *Push* technique, specifically the gesture of passing an imaginary plane in front of the user to confirm selection (or generating a "click"); and, consequently, also inspired the *Hold* technique.

2) Navigation

Bowman et al. [7] subdivide navigation in two parts: travel and wayfinding. Travel is the motor part of navigation, the actions the user does to control the position and/or orientation of his/her point of view. Wayfinding, on the other hand, is the cognitive portion, which consists of thinking, planning and making decisions related to the users' movement. The techniques presented below consist only of travel, leaving completely to the user the wayfinding portion.

One technique that consists in putting the foot in a certain position to navigate is the *Dance Pad Travel Interface*, proposed by Beckhaus, Blom and Haringer [8]. This technique consists of a physical platform (created for the game *Dance-Dance Revolution*), which has directional buttons. The user steps on these buttons and a displacement is created in the direction represented by these buttons. To control the viewing direction the user steps on the directional arrows. One of the navigation techniques proposed in this work (*Virtual Foot Dpad*) was inspired by the *Dance Pad Travel Interface*. During the development of this technique a very similar technique was found in the game *Rise of Nightmares* for the XBOX/Kinect console. Bouguila, Ishii and Sato [9] created a physical device, similar to a platform, which detects the user's feet and, when moved a certain distance away from the center, activate movement in that direction. To control the viewing direction the user turns his whole body in the desired direction. Because of this, a portion of the user's field of view might not be occupied by the viewing screen, so the device slowly rotates to align the user to the screen again. This work inspired the idea of allowing the user to completely leave a virtual circle, creating a movement vector with origin in the circle's center in the direction of the user's position. This lead to the creation of the *Virtual Circle* technique.

B. Interaction in Games for Microsoft Kinect®

The following games were tested to identify interaction techniques:

- Kinect Adventures *(http://www.xbox.com/kinectadventures)*
- Motionsports *(http://marketplace.xbox.com/en-US/Product/Motionsports/66acd000-77fe-1000-9115-d80255530850)*
- Kinect Sports *(http://marketplace.xbox.com/en-US/Product/Kinect-Sports/66acd000-77fe-1000-9115-d8024d5308c9)*
- Kinectimals *(http://www.xbox.com/kinectimals)*
- Dance Central *(http://marketplace.xbox.com/en-US/Product/Dance-Central/66acd000-77fe-1000-9115-d802545607d3)*
- Rise of Nightmares *(http://marketplace.xbox.com/en-US/Product/Rise-of-Nightmares/66acd000-77fe-1000-9115-d80253450846)*

The techniques found in these games were given a reference name that aren't necessarily their official names. These techniques are described below.

1) Pause

Microsoft Kinect's system presents a technique we called *Pause*, which doesn't belong to any specific game, but rather the Kinect system itself. This technique consists of the user placing his/her left arm 45 degrees relative to his/her body, as seen in Fig. 1. An icon is shown indicating the user is in the pause pose, starting a counter. Once this counter is finished the game is paused.

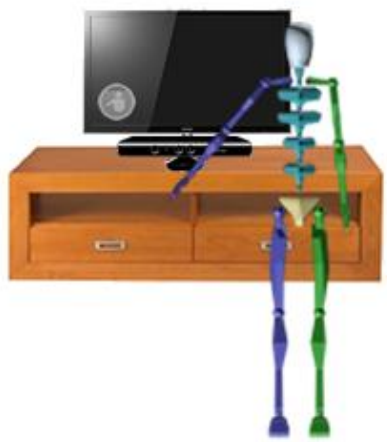

Fig. 1. Pause Technique [10]

2) Hover

The selection menus of most games make use of this technique. To select levels and options through the menu, most games require the user to place his/her hand over the option and a counter will appear. Once this counter is done, the option will be selected or changed to a new value. In some cases the technique is improved with a "snap" behavior, where the hand representation tends to stick to the option even if the user slightly moves his/her hand away. This is done to avoid interrupting the counter in case the user shakes.

3) Walk-In-Place

Amongst the listed games, the sports games make use of *walk-in-place*, which consists of the user moving his/her legs as if s/he was walking (or marching) without moving, in other words, alternately lifting the knees. The speed in which the user does this translates into acceleration in the virtual world, but there is no direction control, which means that the virtual character moves along a specific path. It is also impossible to move backwards. It should be noted, as well, that how high users lift their knees apparently has more influence on locomotion speed than the actual speed with which they do it.

4) Virtual Foot

This technique was found in "Rise of Nightmares" and consists of the user placing his/her foot in front of his/her body in the direction s/he wishes to move, while using his/her shoulders to control the direction of the camera by rotating his/her torso towards the new desired direction.

III. Proposed Techniques

The proposed techniques use information obtained from Microsoft Kinect® as the only data input device. OpenNI [11] was used for communication between the device and the system.

A. *Selection Techniques*

First a virtual hand was developed to follow the user's hand movements in the real world. Moving this virtual hand over objects in the scene enables selection of this object, however the gesture required to select the object depends on which technique is being used. Unlike in Bowman and Hodges [12], due to our work focusing on selection and not exactly manipulation (there are no manipulation-specific gestures, such as a specific gesture to indicate translation, rotation or scale, although objects may be moved around following the virtual hand, while it is selected), we did not find the "lever" problem, where the object is attached to the extreme of a selection ray, making it difficult to properly manipulate the object.

1) Hover

This technique is based on the idea that the user will focus her/his attention on an object when s/he wishes to select it [5]. When the user wishes to select an object s/he needs to hover with the virtual hand over that object. A timer will appear and, once emptied, the object will be selected (Fig. 2). When the virtual hand intercepts a selectable object a "pre-counter" is started, introduced to avoid the "Midas Touch" effect, described by Jacob et al. [13]. This allows the user to freely move the virtual hand without actually triggering many visual timers all the time.

There are two ways to de-select an object with this technique. The first requires the user to move the virtual hand away from the selected object and, after a short time, it will be de-selected. This may not be possible if the object is attached to the virtual hand on all 3 axes, so a second de-selection method was created. The second method requires the user to overlap both hands, which will start a timer to confirm the intention of de-selection and, consequently, de-select the object once the timer runs out.

Fig. 2. Hover technique timer.

2) Push

The idea for this technique came from having a virtual plane in front of the user, described by Rodrigues et al. [6]. The user stretches her/his arm and, once it passes a certain threshold, the selection is triggered. The user must then withdraw her/his arm and may interact with the object. To release the object s/he repeats the gesture.

The gesture of stretching the arm is detected through the arm's angle, more specifically the angle between the vectors formed by the elbow to the wrist and the elbow to the shoulder, as seen in Fig. 3. Once the angle reaches a pre-established limit, the system activates the selection (or de-selection). One problem present in this technique, described by Rodrigues et al. [6], is the involuntary movement along the X and/or Y axes while the user performs gesture of stretcing her/his arm. This problem is more noticeable in cases where interaction requires a higher precision or when the object to be selected is very small on the screen, but for larger objects this problem rarely is an issue.

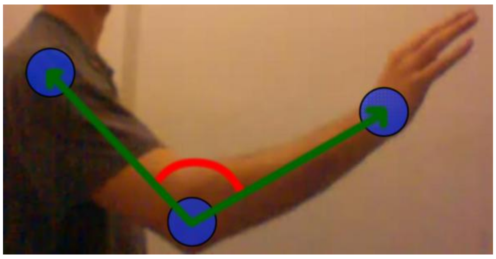

Fig. 3. Arm opening angle.

3) Hold

This technique is based on the previous one, as an alternative. Selection is activated in this technique when the user stretches her/his arm, but, unlike the previous one, s/he must maintain the arm stretched during the interaction (Fig. 4). De-selection is done by withdrawing the arm.

Fig. 4. User stretching arm for hold technique.

B. *Navigation Techniques*

To further enhance the interaction experience the user can be allowed to select objects and navigate through the scene. To enable this, three navigation techniques were created. Also, two techniques were created for camera direction control, which are used in conjunction with movement techniques to create the actual navigation techniques.

1) Camera Control Techniques

For camera direction control we have created *Body Turn* and *Arm Lift*.

a) Body Turn

Two of the proposed techniques use *Body Turn* to control the view point orientation. *Body Turn* consists of the user turning her/his shoulders in the direction in which s/he wishes to rotate the view point, while maintaining the central direction of the body facing the screen. This allows the user to control the view and movement direction without the screen exiting her/his field of view.

b) Arm Lift

Arm Lift can be used instead of *Body Turn* by the same two techniques. The technique consists of the user raising her/his arm straight out to the left or right, with the elbow bent in a 90 degree angle, in order to rotate the camera to the corresponding direction. In (Fig. 6) there is a user raising his right arm to rotate the camera to the right.

Unlike *Body Turn*, this technique will not cause users to turn the camera by mistake while trying to select an object, however, since it the technique requires specific movement of the arms, it can hinder the process of selecting objects. Furthermore, while *Body Turn* may cause users to lose balance while navigating, this technique does not cause a major shifting in the user's balance.

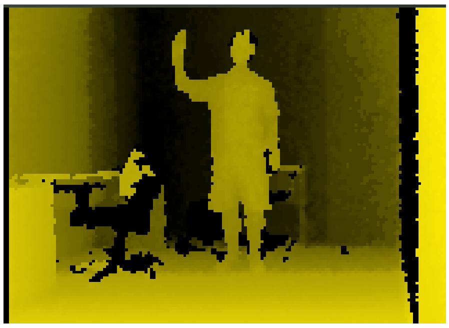

Fig. 5. Dial Directional Pads.

2) Movement Techniques

a) Virtual Foot Directional Pad

This technique was inspired by the work of Beckhaus, Blom and Haringer [8], where they created a physical platform on which the user steps on directional arrows to move in the corresponding direction. The idea was to make a virtual version of this platform (Fig. 6). Three joints were used to achieve this: torso, left foot and right foot. The distance of each foot to the torso is calculated and, once one of the feet reaches a certain distance a movement is generated in that direction. This technique uses the previously described *Body Turn* to allow the user to control the view point orientation.

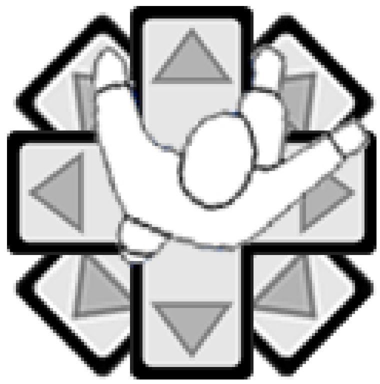

Fig. 6. Virtual Foot Directional Pad concept.

b) Dial Directional Pads

Based on first person games for touch screen devices, such as *iPhone* and *iPad*, this technique uses dials that the user interacts with using virtual hands (Fig. 7). The idea is that it works in a fashion similar to a touch screen, but in larger scale and, instead of using fingers on a screen, the user uses hands. Two dials are displayed on the screen, one in each inferior corner. To the left is the movement control dial and to the right is the view point orientation dial. The user places her/his hand over the dial and stretches the arm to activate it.

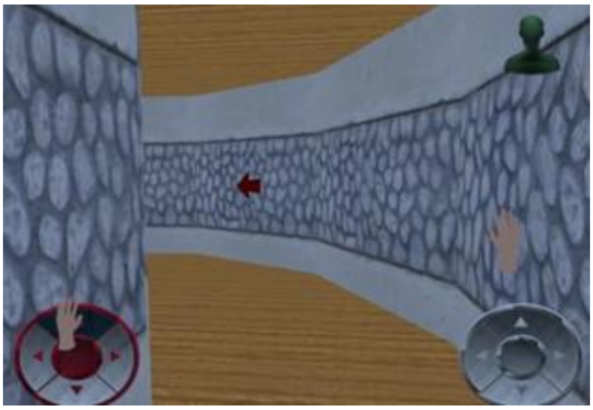

Fig. 7. Dial Directional Pads.

c) Virtual Circle

In this technique the system needs to store the position from which the user started the interaction and generates a virtual circle at this spot. The circle is fixed and the user can be compared to an analog joystick. To move in any direction the user simply moves in that direction enough to leave the virtual circle. A vector is then created from the center to the circle to the user's current position, defining direction and speed of the movement (Fig. 8). To stop the movement the user steps back into the circle. For view point orientation the technique uses *Body Turn*.

Fig. 8. Virtual Circle movement vector.

IV. EVALUATION AND ANALYSIS OF TEST RESULTS

1) Evaluation

Selection and navigation tasks were identified for the tests in a 3D virtual environment to exercise the interaction techniques being evaluated.

Three use scenarios were defined for execution of the tasks and evaluation of the interaction techniques, described below.

After each scenario the user answered a questionnaire, totaling 60 questions, measuring, on a scale of 1 to 7, mental effort (or, in other words, cognition), ease of use and adequacy.

a) Scenario 1

In the first scenario only navigation was contemplated, alternating between the three navigation techniques proposed in this work. This scenario was a corridor, with two 90º curves and a section with a U-turn. The user needed to reach the end of this course, where there would be a red light. Once close enough to this light it would turn off and the user needed to turn around and go back to the initial point.

b) Scenario 2

In this scenario only selection was tested, alternating between the three selection techniques proposed in this work. In this scenario the user had a control panel placed in front of him/her containing a series of levers and buttons (Fig. 1). The user needed to first press several buttons following a specific order, according to which one was lit. After that a series of three red levers needed to be dragged up or down a track to a specific point and released once the indicator showed an acceptable position. At last, two green levers needed to be manipulated simultaneously until the end of their respective tracks.

c) Scenario 3

In this scenario navigation and selection were evaluated, alternating between the navigation and selection techniques. For this test we discarded *Dial Directional Pads*, because this technique makes use of hands, potentially creating conflict with the three selection techniques. Similarly, *Arm Lift* was discarded due to inherently conflicting with some selection techniques, but still should be considered for future studies. The other two navigation techniques were used in combination with the three selection techniques, creating a total of six combinations. Each of these combinations were tested. This scenario tested the proficiency with buttons and levers, besides a new task: carry a ball while navigating and interacting with other objects at the same time (Fig. 9). In this scenario we were able to see the impact of the techniques in a game-like environment.

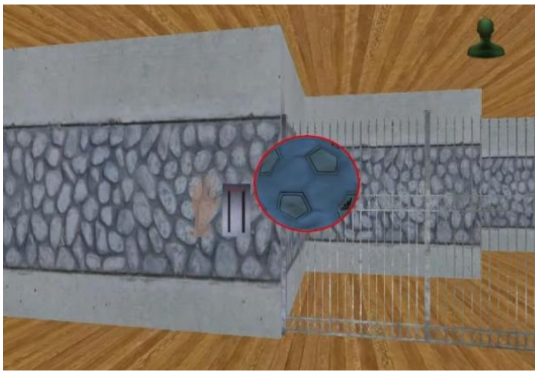

Fig. 9. User carrying a ball while navigating in Scenario 3.

The order of the tests was changed for each user to avoid that learning had any influence in the general result of the test. In total 9 users were evaluated during the tests using the same physical set up: a room with enough space for free movement with a single large screen.

2) Quantitative Analysis of the Results *a) Navigation*

It is possible to observe a relation between metal effort and the degree of interaction fidelity of each technique. Interaction fidelity is a characteristic of each technique, there is, as of currently, no standard measurement, but it is possible to observe and relate the virtual action to a real life action and indicate if a technique has greater or lower interaction fidelity. *Virtual Circle* had the greatest degree of interaction fidelity and, consequently, demanded less mental effort from the users. Similarly, *Virtual Foot*, which had the second greatest degree of interaction fidelity, demanded greater mental effort.

Bouguila et al. [14] evaluated user paths by recording samples of the user's position at certain intervals. The same type of evaluation was used here. Comparing one leg of the path amongst the three techniques (Fig. 10, Fig. 11) it is possible to observe that the users had a considerably better performance during the U-turn when using *Virtual Circle* because the curve is much smoother and follows an optimal path in the average case. However, to walk in a straight line they performed better with *Virtual Foot*. The reason behind this is that *Virtual Circle* is completely analogical, so if the user moves slightly to any side the movement vector will not be 100% parallel to the walls, creating a slight deviation to one of the sides. This is visible in the initial part (from starting point until the first curve).

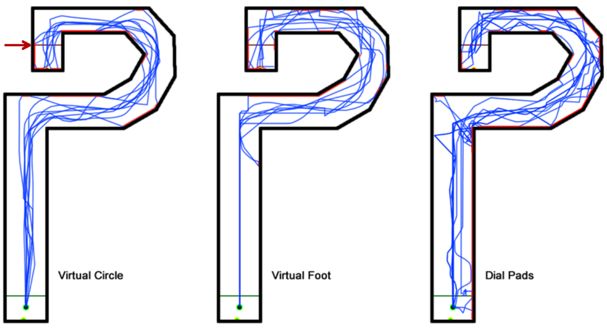

Fig. 10. Path outline for the first leg of the course.

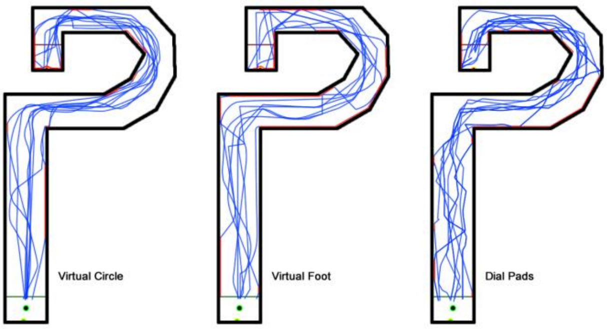

Fig. 11. Path outline for the second leg of the course

With the information of collision percentage (the amount of time a user spent colliding with any walls over the amount of total completion time) of the users we were able to identify three different thresholds to categorize the users: below 10%, between 10 and 30%, and above 30%, as shown in Fig. 12. The major reason that caused this difference was the concern each user had with not hitting walls. Although they were asked to avoid hitting the walls, certain users clearly didn't worry about it.

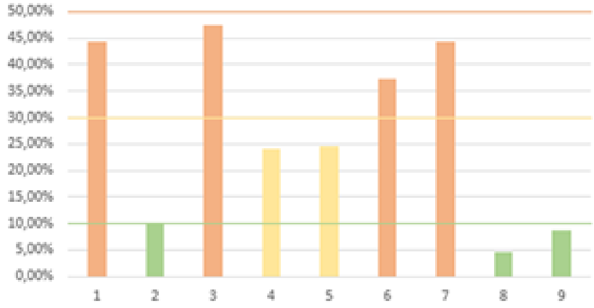

Fig. 12. Users collision percentage.

The graph shown in Fig. 13 reinforces that the reason for such a difference in collision percentage was due to user behavior instead of difficulty of use. The graph shows that the group of users with higher percentage of collision, in average, completed the navigation task in less time.

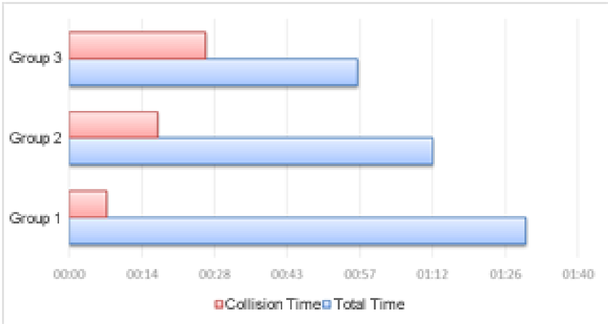

Fig. 13. Collision Time x Total Time.

b) Selection

The repetition of the gesture for selection and de-selection, present in the *Push* technique, did not please the users, who had trouble with that. *Hover*, on the other hand, was criticized for introducing a delay to be able to select an object, being the least immediate of the three techniques. Despite this, *Hover* was the preferred technique in all tasks. Oppositely, *Push* was the worst in the opinion of the users.

It was made clear that for tasks that require high precision, such as the case of the red levers, the involuntary movement along the X and Y axes highly hinders the interaction, consequently affecting the users' preference of the technique.

Hold was the middle-term in preference, the users found no problems with the selection and de-selection, as well as not having the forced delay found in *Hover*, but the involuntary movement along the X and Y axes was the huge downside that ultimately frustrated users, weighing *Hold* down.

Curiously in selection, contrary to navigation, the technique with least interaction fidelity was the one the users preferred. Bowman et al. [7] speak about interaction fidelity, questioning if a technique with higher interaction fidelity means it is necessarily better. While recognizing the value of high-fidelity techniques, it has been discussed that not everything can be done in a natural way, and the results found in our tests indicate that, indeed, higher fidelity may not always be the best.

c) Combination of Navigation and Selection

When comparing directly the navigation techniques, we observed that the *Virtual Circle* technique was, in fact, considered slightly better in pair with selection, while the mental effort was very similar, showing that the change in navigation techniques did not have great impact on selection. However, it is possible to observe that strictly comparing navigation tasks, the users preferred *Virtual Circle*.

The technique that had most user technical faults (executing actions by mistake) was *Hold*, with large difference to the second placed technique *Push*. *Hover* did not have any mistakes of this type. These errors were caused by the user withdrawing her/his arm when s/he shouldn't have.

Fig. 14 shows the average execution time for the tasks, considering the order in which they were performed, not sorted by technique. The average time was considered for each 1st task of all users, then for each 2nd task, and so on. The completion and collision timings show that, no matter which technique combination used, there is a learning curve, indicated by the decreasing lines for task completion. The 4th task causes an increase in completion time compared to the 3rd task. This is due to changing the navigation technique: the first three tests were applied using one of the navigation techniques, then the last three were applied using a different technique.

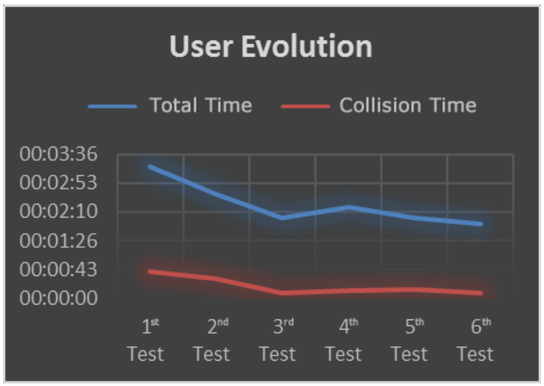

Fig. 14. User evolution based on average test execution times.

The combination of navigation and selection consolidated *Hover* as the overall preferred technique by the users. This preference happened because the users felt more secure to carry objects while navigating, since they didn't have the risk of accidentally dropping the ball.

Besides that, *Virtual Circle* continued to be the preferred navigation technique, but not as evidently as in the first scenario. This was because, in the third scenario, the user was less prone to collision since the environment was more ample than the first, which had narrow corridors.

3) Qualitative Analysis of the Results

Here we analyze some events that occurred during the interaction with the system in any scenario, categorizing them and explaining the reason for them happening. The events have been categorized by: E (equipment/test environment), T (interaction technique), and C (user comprehension failure). The frequency varies from 1 (low) to 7 (high). The events are displayed on Table 1.

Table 1 – Events detected during user interaction

Event	Frequency	Category
Lack of precision due to shaking caused by tracking	6	A
Undesired actions due to tracking failure	5	A
Undesired movement along the X and Y axes	7	T
Difficulty to stop or move along the desired direction	5	T
Accidentally turn while trying to select	5	T
Difficulty in aligning camera orientation as desired	4	T
Physical fatigue	2	T
Loss of balance while trying to move	1	T
Incorrect gesture	3	C
Failure in virtual space comprehension	2	C
Confusing movement direction with camera direction	1	C

a) Lack of precision due to shaking caused by tracking

The red levers in the second scenario were the most affected by this problem. Many times the user would correctly and cautiously perform the task, but ended up missing the position due to the shaking caused by the tracking system.

b) Undesired actions due to tracking failure

This event happened often and was due to some joints being incorrectly calculated from the tracking system and, depending on the result, could incur in undesired commands or movements.

c) Undesired movement along the X and Y axes

This event was another problem that caused a poor performance in the red levers task in the second scenario, but also happened quite often in the third scenario. Due to having to stretch his/her arm, in *Push* and *Hold* techniques, the user sometimes moved it along some other axis by mistake, making the object move in a way s/he did not expect.

d) Difficulty to stop or move along the desired direction

This event was mostly seen in the technique *Virtual Foot* while the user was trying to move backwards. S/he would correctly place his/her foot behind the body, but sometimes the system would interpret it as a forward movement. Another occurrence was when the user would try to stop moving in the *Virtual Circle* technique, because the time it took for the user to move back to the center of the circle caused the user to move more than desired. At last, in the *Dial Pads* technique the user sometimes would accidentally press the some button other than the desired, usually when s/he relaxed the arm down, causing the lower button to be pressed by mistake.

e) Accidentally turn while trying to select

This event was only seen in the last scenario, when selection was combined with navigation. When the user would try to select an object, due to stretching the arm, s/he sometimes accidentally activated *Body Turn*.

f) Difficulty in aligning camera orientation as desired

Some users complained about the accuracy with *Body Turn*. When they would try to turn the camera towards a certain direction sometimes the camera would turn too much, causing them to waste time trying to point the camera to the correct direction or would give up and compensate the skew using sidesteps.

g) Physical fatigue

Few users reported physical fatigue, mostly present in *Body Turn* for navigation and *Hold* and *Push* for selection, especially during the red levers task in the second scenario.

h) Loss of balance while trying to move

Few users reported this problem, but always with the *Virtual Foot* technique. While trying to place one foot forwards at a sufficient distance for the system to recognize the command, some users felt a loss of balance, which was even stronger when trying to make a curve due to having to turn their torso in *Body Turn*.

i) Incorrect gesture

This event occurred most during *Push* and *Hold* techniques, since they are similar. In most cases the user would keep his/her arm stretched while they shouldn't or vice-versa, which sometimes caused the system to detect commands that the user did not actually wish to make.

j) Failure in virtual space comprehension

In a few cases the user would calculate the distance of certain objects incorrectly or get lost in the virtual environment, even if only momentarily. This happened most in the third scenario.

k) Confusing movement direction with camera direction

Sometimes it was possible to notice the user trying to rotate the camera turning his/her foot instead of their torso in the desired direction.

V. CONCLUSION AND FUTURE WORK

One of the advantages that were initially predicted with these techniques was the possibility of interacting with both hands at simultaneously, a possibility not currently easily supported by conventional devices, such as gamepads or mouse and keyboard. To evaluate this advantage, amongst others, as well as limitations imposed by the techniques, we had to develop user tests. Through these tests we identified which techniques allow a satisfactory interaction, enabling the user to perform tasks in a virtual environment, such as exploring and interacting with objects (despite not being able to rotate and scale them, the users could select and move them).

It was possible to observe that there is clearly a learning curve and, after several tasks, the users would discover ways to use the techniques in which they felt more comfortable. Even though no techniques, in general, had a poor performance, each user, in the end, felt more comfortable with a certain navigation and selection technique. Despite this, it was not possible to compare these techniques with techniques the users were already familiar with, due to the possibility of using both hands simultaneously, ruling out devices traditionally used for interaction.

At last, it was possible to verify that Microsoft Kinect® enables the creation of techniques with high degree of interaction fidelity that allow several user actions in a virtual environment in a comfortable manner, besides increasing the user's virtual presence. After some improvements, especially in the implementation of the techniques, we believe that they can be used in games to control a character and, possibly, to perform more complex tasks than currently possible, mainly due to the possibility of using both hands simultaneously. This last possibility can largely improve gaming experience, demanding players to perform more complex tasks that require use of simultaneous actions.

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REFERENCES

[1] J. Massó, "A Structured Approach to the Development of 3D User Interfaces", Albacete, Spain, 2008.

[2] R. McMahan, D. Bowman, D. Zielinski and R. Brady, "Evaluating Display Fidelity and Interaction Fidelity in a Virtual Reality Game", IEEE Transactions on Visualization and Computer Graphics, 2012.

[3] S. Gerathewohl, "Fidelity of Simulation and Transfer of Training: A Review of the Problem," Federal Aviation Administration Office of Aviation Medicine Report, 1969.

[4] D. Bowman e L. Hodges, "Formalizing the Design, Evaluation, and Application of Interaction Techniques for Immersive Virtual Environments", Journal of Languages and Computing, 1999.

[5] L. Sibert and R. Jacob, "Evaluation of Eye Gaze Interaction", 2000.

[6] P. Rodrigues, A. Raposo and L. Soares, "A Virtual Touch Interaction Device for Immersive Applications", 2011.

[7] D. Bowman, E. Kruijff, J. LaViola e I. Poupyrev, 3D User Interfaces: Theory and Practice, 2005.

[8] S. Beckhaus, K. Blom and M. Haringer, "Intuitive, Hands-free Travel Interfaces for Virtual Environments", in New Directions in 3D User Interfaces Workshop of IEEE VR, 2005.

[9] L. Bouguila, M. Ishii and M. Sato, "Virtual Locomotion System for Human-Scale Virtual Environments", in Working Conference on Advanced Visual Interfaces, 2002.

[10] Microsoft, "Kinect game tips", [Online]. Available: http://support.xbox.com/en-US/games/xbox-games/kinect-games#1d40a96507834b2f86ef49f0a3762

[11] OpenNI, "OpenNI", [Online]. Available: http://openni.org/.

[12] D. Bowman and L. Hodges, "An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments", in Proceedings of the 1997 Symposium on Interactive 3D Graphics, 1997.

[13] R. Jacob, J. Leggett, B. Myers and R. Pausch, "An Agenda for Human-Computer Interaction Research: Interaction Styles and Input/Output Devices", Behaviour & Information Technology, 1993.

[14] L. Bouguila, F. Evequoz, M. Courant, B. Hirsbrunner, “Walking-Pad: a Step-in-place Locomotion Interface for Virtual Environments”, in Proceedings of the 6th International Conference on Multimodal Interfaces, p. 77-81, 2004.