Tangible Windows for a free Exploration of Wide 3D Virtual Environment

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ABSTRACT

Exploring virtual environment with immersive metaphor is still largely unexplored, with the costly CAVE exception. This question takes importance in lots of fields, such as fluid mechanics, where space and time resolved dataset become more and more common. For that reason, we present an interaction design study of an window exploration metaphor, for large 3D virtual environment. The metaphor is based on the use of a tablet as a tangible and movable window on a virtual environment. Rotations in the environment are tracker-less mapped on the rotations of the tablet. Our design is inspired by fluid mechanics issues, but is build keeping generalizability in mind. The study shows that mapping three degrees of freedom onto corresponding real three degrees of freedom of space raises the transparency, the efficiency of data exploration and the space awareness of users.

Categories and Subject Descriptors

H.5.1 [**INFORMATION INTERFACES AND PRESENTATION**]: Multimedia Information SystemsAugmented and Virtual realities; H.5.2 [**INFORMATION SYSTEMS**]: Information Interfaces and Presentation User Interfaces

Keywords

Data exploration, Virtual Reality, Navigation, Interaction Technique

1. INTRODUCTION

Exploring a virtual environment is now a common task in numerous field. Video games, for instance, often allows the exploration of large virtual world [6]. This exploration is usually two dimensions -the character is basically exploring a map. Fluid mechanics is another typical example, with dataset nowadays in four dimension and three components, as numerical and experiences are space and time resolved [3]. The field of scientific visualization is under heavy development, but the exploration of dataset is still little explored, except with the use of important infrastructures like CAVE [2], which demands heavy infrastructures.

A lot of scientific vizualisation works are focused on 2D representations. Navigating from a point of interest to another point of interest, as important as it may be, is still complex, especially for 3D dataset [10, 4, 7]. Yu *et al.* has shown [12] how scientific visualisation may be limited by the use of 2D input for navigating in 3D space. However, most of constrains may be taken out by specific metaphors [9]. Helps, indications and complex metaphors are often necessary to fulfil tasks [1].

The emergence of stereoscopic devices has been followed by lots of works. For instance, recently, Klein *et al.* [7] proposed a direct-touch stereoscopic design to explore fluid mechanics data. If depth perception is somewhat solved, the question of how mapping numerous degree of freedom is still open [11, 5].

To partially overcome this problem, we present an interaction design of an exploration metaphor on tactile tablet. We extend Scarpa *et al.* work [8] by achieving a rigorous study, extending drastically the working environment, and proposing a tracker-less approach. The metaphor is based on the use of the tablet as a tangible and movable window on a virtual environment. Rotations in the virtual environment are mapped on the rotations of the tablet, in a more transparent way for users. Moreover, we will show that it improves the experience. In addition, parallax effects gives access to a strong 3D immersion.

2. TURNABLE WINDOW ON VIRTUAL REALITY ENVIRONMENT.

The main objective of this study is to set the tablet as a turnable window onto a virtual scene. A displacement of the tablet will change the point-of-view of the camera.

As the tablet is very movable, exploring the scene is supposed to be effortless. By mapping the three rotations of the tablet to the orientation vector in the scene, we hope for an improvement of the transparency of the exploration metaphors. Rotations are acquired with the gyroscopic sensors of the tablet. Actually, three degrees of freedom are

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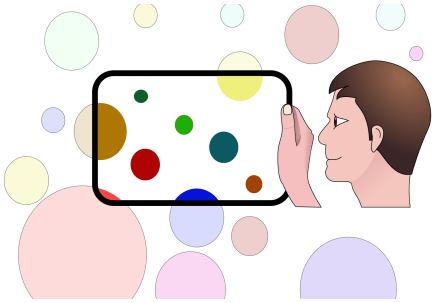

Figure 1: Window on virtual environment.

mapped onto the natural three degrees of freedom of the users. The complexity of the interaction interface is then expected to be minimized [11].

Another advantage is, as the metaphor is natural, better reactivity and shorter training phase are expected.

Mapping rotations allows an extra side effect. Due to permanent small rotations, parallax effect will occur at every moment and will give a strong depth perception. The 2D scene representation appears to be in 3D. We therefore expect an improvement of the spatial perception of users. Only one dimension of displacement is proposed, in the camera direction. As exploration was our objective, adding a strafing metaphor was discarded.

3. DESIGN

Exploring a virtual reality environment may have numerous applications, such as fluid mechanics, astronomy, or simply visiting a house for sale. We make up an environment to test the proposed metaphor, with keeping in mind the generalizability of the design.

The scene is composed by a few hundreds of sphere (500). The position, the color and the diameter of spheres were random in the scene. The light is strengthen at the center of the view, as if the subject is holding a flashlight. The reason is to incitate the subject to explore the scene by given partial awareness of the environment. As targets, a few eggs (3) are hidden in the scene, with, as for spheres, random diameter and color. Seeking for eggs force subjects to explore a large part of the scene. The choice of eggs was driven by the difficulty to discriminate an egg from a sphere under some point of view. When found, eggs are highlighted with a circle. A typical view of the software in use can be seen in figure 2.

4. EXPERIMENTAL STUDY

4.1 Hypothesis

Our main assumptions are:
-**H1**: Subjects explorate a larger space with the window method
-**H2**: Finding a target takes less time with the window method
-**H3**: Subjects prefer the window method

4.2 Conditions

The scenario is to find any of the eggs, though participants were allowed to continue the exploration until the time out.

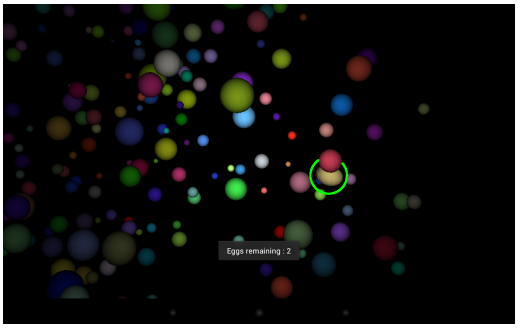

Figure 2: General scene design, with a found egg, highlighted with a green circle, and spheres. Flashlight-like enlightenment is visible, as an incitation for exploration.

Condition **C1** is with the use of the window metaphor. For the comparison condition **C2**, the rotations have been replace by familiar gestures for angular movement, named as "game pad controller". Practically, the derivated of the two main angles were mapped on a joystick widget. We integrate a slider to allow the displacement in the camera orientation, both forward and backward. Obviously, spatial properties are isotropic.

4.3 Hardware and Software setup

The experiment was run on a Nexus 7 tablet. It weights 340g. The experimental software was a custom made OpenGL ES 1.1 renderer. The tracking of rotations was done with the internal gyroscopes. Source code is available on request.

4.4 Participants

Fourteen participants (only men) recruited at the LIMSI lab (University of Paris-Sud), aged between 20 and 27 years old completed the experiment. The mean age was 24 years old (standard deviation $\sigma = 2$).

4.4.1 Measures

The following measures were collected for each run of any condition:

-**MO1**: Number of eggs found over time
-**MO2**: Displacement over time
-**MO3**: Angular displacement over time

In addition to these measures, we present to participants a short questionnaire on a 5 point Likert scale for the subjective evaluation of each metaphor, investigating participants' fondness between the two approaches:

-**MS1**: Moving forward and backward
-**MS2**: Rotating in the scene
-**MS3**: Finding eggs – Difficulty of the task
-**MS4**: Finding their way – Difficulty to self-localization

4.4.2 Procedure

Subjects sit on a desk chair and are free to hold the tablet how they feel at ease. No payment was offered.

Before the experiment, we describe briefly both metaphors. The experiment begins with a short training case. For each

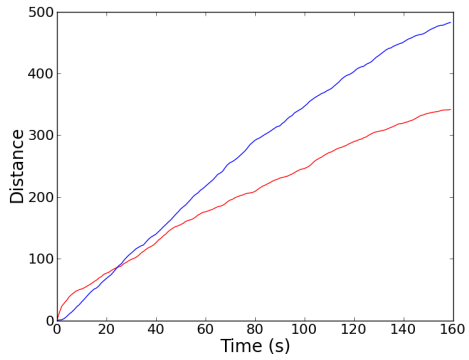

Figure 3: Mean of distance crossed per participants over time until time out. Blue is for the window metaphor, while red is for the tactile condition.

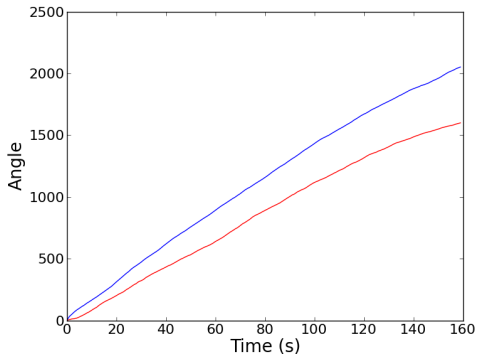

Figure 4: Mean of the angle turned per participants over time until time out. Blue is for the window metaphor, while red is for the tactile condition.

scenario, subjects try to find as many eggs as possible. After 160s, the scenario ends. They repeat this scenario three times. The experiment ends with a short questionnaire.

5. RESULTS

In the following, statistical tests use the Wilcoxon signed-ranked test, since populations do not respect Gaussian laws.

The completion time (when **MO1** = 1) , in mean (t = 70.3s), 23.4% inferior with the window method. It is a tendancy, comparatively to the condition **C2** (mean time of $t = 86.8$s), with a p-value of $p = 0.091$.

As finding eggs involve exploring the scene, it indicates the window method is more suited for explorating tasks. Moreover, the displacement **M02** (see figure 3) surprisingly indicates that participants have travel along a significantly larger distance when using the window method (the mean difference is 40.0% at the final time , with a p-value $p \ll 0.01$). As expected for a supposedly more intuitive metaphor on rotations, the seen angle **MO3** (see figure 4) is also significantly larger with the proposed method (the mean difference is 29.0% at the final time , with a p-value $p \ll 0.01$). The hypothesis **H1** is therefore true.

We consider the fraction of participants having found an egg over time (see figure 5) extracted from **MO1**. It shows

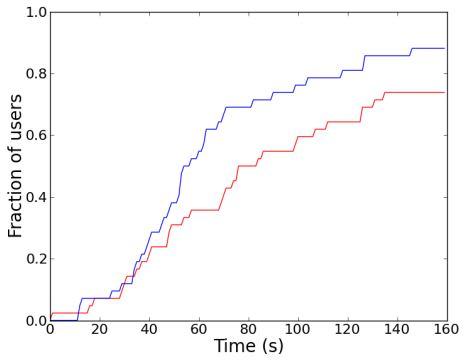

Figure 5: Fraction of participants who have found an egg, over time until time out. Blue is for the window metaphor, while red is for the tactile condition.

three main times in the exploration. Until $t \approx 40$s, curves are similar. Participants randomly found an egg close to their initial position. Next, until $t \approx 70$s, the gap between the conditions **C1** and **C2** is increasing. This is where the influence of the proposed metaphore is the strongest. Then, the gap is very slowly decreasing. Lots of participants have already found the egg in **C1**, therefore participants in **C2** are catching up. At reference time $t = 70.3$s, when participants have found the egg in condition **C1**, participants in condition **C2** have still not found one (high significant, p-value $p = 0.0088$ according to the McNemar's test). It strongly confirms the above statement, the tendancy that subjects founds an egg with shorter time when exploring the scene with the window-based method. The hypothesis **H2** is then verified.

The **MS2** measures show that subjects significantly prefer the window metaphor ($p = 0.012$) which validates **H3**. It is empowered by the fact that **MS4** is significantly better for the window metaphor ($p = 0.037$).

Table 1: Activity during experiments, in percentage of the total time.

	Condition **C1**	Condition **C2**
Rotation	47.2%	30.7%
Translation	12.8%	24.0%
Rotation + Translation	11.2%	4.80%

The fact that participants travel a larger distance in the window metaphor was not expected. The displacement was mapped on the same slider widget in both conditions. As a matter of facts, subjects do not feel any difference in the displacement – as it can be seen in figure 6, the box for displacements are comparable. Still they travel more. Surprisingly, subjects use 96% more the displacement widget in the window metaphor (a mean of 17.1 activations per minute for first scenario, to be compared to 8.6 activations per minute in the game pad controller based scenario) but for a total amount of time almost twice inferior. Consequently, their mean velocity is also higher ($32,2\%$ higher). As stated above, **MS4** is significantly better for the window metaphor, subjects have less difficulty to self-localized themselves. It means that subjects know where to move for exploring new areas of the scene, so they do it straightly. It is empowered

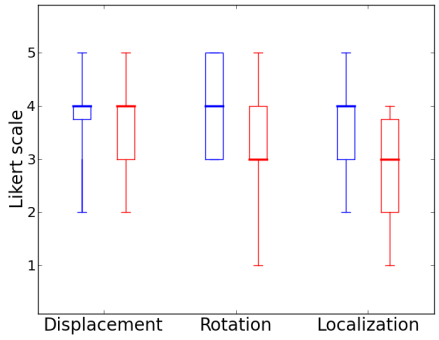

Figure 6: Box plot for subjective answers. Blue is for the game pad controller based scenario, and red for the window metaphor condition. Thick line is the median of data, where the box correspond to 1st and 3rd quartiles. Plain lines represents maximum and minimum values. Couples of box corresponds respectively to MS1,MS2 and MS4 measurements.

by the fact that, in condition **C1**, subjects spend only 28.8% of the total time doing nothing when subjects in condition **C2** spend 40.5% of the time doing nothing. This difference is highly significant (p-value $p \ll 0.01$).

Moreover, participants move *and* rotate as much as they just move when using the proposed metaphor. On the contrary, they move *then* rotate when using the game pad controller based scenario. They spend only 4.8% of the total time, a twice of the amount of time in **C1**, of rotating and moving. This measurements, directly derived from **MO2** and **MO3**, is highly significantly different ($p \ll 0.01$), and can be found in table 1. Then, the proposed metaphor allows to control simultaneously more degrees of freedom than the game pad controller based scenario. The proposed interface is actually more *transparent* that the tactile one, which explains **H3** trueness.

Overall, subjects think of the task of finding eggs as hard to complete in both conditions (the median of **MS3-** is 2 with small dispersion on the Likert scale for both **C1** and **C2**), which was important to force subjects to explore the scene.

6. CONCLUSION AND FUTURE WORK

In this paper, we have presented a concept: using a tablet as a motional window on a virtual environment. Mapping users' degrees of freedom of rotations directly on the displacement in the virtual world has been implemented. We design a scene and rigorously experimented the proposed metaphor. We showed that the window metaphor is suited for the exploration of virtual environment. Moreover, using the tablet as a motional window is also faster for seeking targets. We explained, based on objective measurements, why participants prefer the proposed metaphor, as an indirect proof of the augmentation of transparency. Initial project was to map the six degree of freedom of movement of the tablet onto the six degree of freedom of movement in the virtual space. It is regretful that the accelerometer sensors give noisy response. With data analysis, a tendency of the translation of the tablet is computable, but a strong drift is appearing quickly due to integration errors. Self-localizing rapidly become impossible. Nevertheless, the augmentation of transparency showed by the experiments leads to an improvement of the use of others well-known metaphors such as a slider. The development was done keeping in mind generalization, especially for scientific visualization from one dimensional-three components fields like pressure field to high dimensional-three components fields, or serious game interface, for instance visiting house-for-sale. The proposed metaphor is natural. We assume it has better reactivity and shorter training phase and it will be rigorously experimented in future works.

7. ACKNOWLEDGEMENTS

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