# Evaluation of Smartphone-based interaction techniques in a CAVE in the context of immersive digital project review

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## ABSTRACT

Immersive digital project reviews consist in using virtual reality (VR) as a tool for discussion between various stakeholders of a project. In the automotive industry, the digital car prototype model is the common thread that binds them. It is used during immersive digital project reviews between designers, engineers, ergonomists, etc. The digital mockup is also used to assess future car architecture, habitability or perceived quality requirements with the aim to reduce using physical mockups for optimized cost, delay and quality efficiency.

Among the difficulties identified by the users, handling the mockup is a major one. Inspired by current uses of nomad devices (multi-touch gestures, IPhone UI look'n'feel and AR applications), we designed a navigation technique taking advantage of these popular input devices: Space scrolling allows moving around the mockup.

In this paper, we present the results of a study we conducted on the usability and acceptability of the proposed smartphone-based interaction metaphor compared to traditional technique and we provide indications of the most efficient choices for different use-cases accordingly. It was carried out in a traditional 4-sided CAVE and its purpose is to assess a chosen set of interaction techniques to be implemented in Renault's new 5-sides 4K x 4K wall high performance CAVE.

The proposed new metaphor using nomad devices is well accepted by novice VR users and future implementation should allow an efficient industrial use. Their use is an easy and user friendly alternative of the existing traditional control devices such as a joystick.

**Keywords:** interaction technique, navigation technique, virtual reality, augmented reality, nomad devices, immersive room, simulation, CAVE

## 1. INTRODUCTION

Immersive digital project reviews consist in using virtual reality (VR) as a tool for discussion between various stakeholders of a project. In the industry, the product is the common thread that binds them together, and for Renault, a French multinational vehicle manufacturer, part of the Renault Nissan Alliance, the product is represented by a digital car prototype model used for immersive digital project reviews between designers, engineers, ergonomists, etc. The digital mockup is also used to assess future car habitability or perceived quality requirements in order to avoid using physical mockups for optimized cost, delay and quality efficiency.

Interactions are among the most fundamental parts of virtual reality processes that can provide to the user full immersion and a sense of presence. There are many tasks one would like to achieve in a virtual environment, and there are two main types of approaches to deal with this problem. On the one hand, the quest for realism consists in reproducing virtually and exactly the reality and the sensations one could feel in the real world. To manipulate an object, one would use his hand and handle it with force feedback which is known as haptic. To move, one would simply walk using treadmills. On

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the other hand, interactions techniques offer abstract mechanisms to perform more challenging tasks efficiently. For example, one would use ray-casting, point his index finger or a stick at something and trigger a selection, point at somewhere to go or use a game controller and navigate with a joystick. It's the VR version of a graphical user interface (GUI).
While the realism quest loses all the benefits of virtual environments by sticking too closely to reality, interaction techniques do the opposite by proposing mechanisms which would be unrealistic or impossible in a real world. They bypass the physical constraints (e.g., the size of the immersive room) allowing greater freedom of action, thus requiring greater attention to enable intuitive controls. On the other hand they may induce some artefacts, among them physiological discomfort or even sickness, called simulation sickness or cybersickness.

In a previous study we proposed new interaction techniques to be used in a CAVE. Inspired by current uses of nomad devices (multi-touch gestures, IPhone UI look'n'feel and AR applications), we have implemented an early feature set that takes advantage of these popular input devices such as a virtual mirror displayed directly on its screen, a magical lens which overlays information on the virtual world and allows annotation, a selection technique and a navigation technique. Among the identified difficulties in efficiently interacting with the virtual environment, handling the mockup is a major one. We designed a navigation technique taking advantage of these popular input devices: Space scrolling allows moving around the mockup.

In this paper, we present the results of an evaluation study we carried out comparing the friendliness and efficiency of the proposed smartphone-based interaction metaphor to a traditional technique and provide indications for more efficient choices for different use-cases.

Figure 1 : Renault's test platform 2IP (left) and new IRIS CAVE (right)

## 2. STATE OF THE ART

Moving around is one of the most basic tasks one would like to achieve in a virtual environment. While head-tracking has made it possible to travel naturally by simply walking, the explorable virtual space is often constrained by real space (e.g. the walls of an immersive room), hence the need of travel techniques. Moreover, these techniques could provide means of faster travelling. A short overview of existing techniques is given in this section.

### 2.1 Walk based techniques

Redirected Walking [1] and Motion Compression [2] are techniques that allow one to explore large virtual environments by walking naturally, even though the real room has limited space. This technique is based on research suggesting that vision often dominates vestibular sensations. It consists in fooling the user by bending imperceptibly his path so that he remains in the boundary of the room.

Walking-in-place [3] is based on the idea that interactions techniques that look like reality improve presence feeling in virtual environments. In the case of locomotion, this technique allows the user to move by miming walk. One refinement called Redirected Walking in Place [4] handles the case where there is a missing side in an immersive room by fooling the user into always looking at the opposite.

Step WIM [5] is an alternative version of WIM in which the user walks on a miniature version of the world placed on the floor, making it possible to reach distant places. The user can invocate the WIM by tapping his toes, walk on it and then make it disappear.

The Seven League Boots [6] let the user walk 7 times faster by pressing a button. The main drawback is that the user may still hit into a wall and should often readjust his position in the room.

### 2.2 Metaphor based techniques

With Pen and tablet [7], the user can specify his destination and be brought there. The map and the user's avatar are displayed on the tablet, while the pen is used for pointing where to go on it. The user is then smoothly taken to the destination by following a generated path or teleported there. As we have seen before, WIM [8] allows for interactions with a miniature of the world. Combined with the Pen and Tablet metaphor, it becomes a travel technique: The user can see his avatar in the miniature, grab it and move it where he wants to go. Moreover, the Voodoo Doll [9] we have seen earlier is also compatible with Pen and Tablet as the user can easily create a miniature of the world by grabbing the ground.

Path Drawing [10] is a more immersive version of Pen and tablet in which the user can specify the path he will take. Using ray-casting, the user draws a line on the ground, and then his view smoothly follows it.

As previously seen, grabbing the air [11] allows for manipulations of objects with both hands. When grabbing the air, the technique behaves differently and acts as if the whole world was grabbed. Thus, the user can either zoom out the world and walk like a giant as in Step WIM, or pull the air to himself as if he was pulling a rope.

The Virtual Companion [12] allows the user to drive a virtual animal using reins. He can invocate the companion by joining his hands, drive using well known reins orders (left, right, faster, slower, stop) and dismiss it by crossing his hands.

## 3. SPACE SCROLLING

While the user can naturally walk in the CAVE™, he may want to move faster or to go somewhere outside of the immersive room's limited space. With the idea of proposing an intuitive way of doing such things, we propose an egocentric [13] travel technique based on familiar tactile gestures of Smartphones. The user has to *'scroll the space'* with his thumb as he would scroll a webpage to move forward or backward. This means that a vertical scroll will translate the view in the direction pointed by the phone. For rotation, the user has to scroll horizontally.
A major advantage of this technique is that only one finger is used.

## 4. EVALUATION

To evaluate the "Space Scrolling" metaphor using a smartphone, we compared it to one of the most common navigation technique / input device: the First-Person Navigation using a joy pad. We have implemented it using an XBOX 360 gamepad (Figure 2). 2 axis of the left joystick were used for translations and 1 axis of the right joystick was used for rotations.

### 4.1 POPULATION

Eleven participants (3 females and 8 males) aged from 24 to 57 (M = 33) took part in this experiment. Another two people attended to the experiment but had to give up due to simulator sickness. Seven of them owned a smartphone. Seven of them already played a FPS game with a joy pad. They were all unpaid volunteers and naïve to the purpose of the experiment.

### 4.2 EXPERIMENTAL APPARATUS

The experiment was conducted in Renault's test platform 2IP, a 4-sided CAVE (3 walls and the floor) measuring 3.3 m wide × 3.3 m long × 2.5 m high in a direct projection setup. Each screen uses a mainstream short-range ACER video projector with HD resolution (1024×768) running at 60Hz per eye, and was driven by 2 NVIDIA Quadro 6000 GPU distributed over a 2 machine cluster. Head and hand tracking was performed with an ART 4-camera infrared tracking system running at 60Hz. Software used to generate the simulation were Unity 3D coupled with MiddleVR, running on a Windows 7 environment.

A simple scene was constructed for the purpose of the experiment. It consisted of a fictive Renault's automobile assembly plant (30 m × 20m) with realistic distances, sizes. The different routes to follow covered the entire scene.

Figure 2 : The peripheral used for the experiment with a body of tracking: a Samsung Galaxy SIII (left) and an XBOX 360 gamepad (right)

Figure 3 : The virtual environment used for the experiment

### 4.3 PROCEDURE

Before the beginning of the experiment, a familiarization phase took place so as to accustom participants to the CAVE system, and to show them that they can move with their feet on a limited range. The center of the room was put near a 3D model of a car so they can observe it from different points of view, go inside it, and get familiar with the 1:1 scale visualization. No locomotion metaphor was available and they were just given the instruction to observe the car from different points of view until they are accustomed with the CAVE system.

For each metaphor, the participants were taught how to use it and were given the instruction to explore the virtual environment using the metaphor or physical walking for a few minutes. Then the user was asked to follow a series of 4 different routes, with the first one considered as a training to path following and not recorded. The participants were given the instruction to be as much accurate as possible and to not seek speed. Half of the subjects began the experiment with the joy pad and the other half with the smartphone.

In the experiment, participants performed the Simulator Sickness Questionnaire (SSQ) [15] and the Presence Questionnaire (PQ) [16] after each use of the CAVE as well as Likert questionnaires about the metaphor after each block of tasks. Finally, the participants filled a questionnaire at the end of the session to compare the two metaphors. Each task lasted about 15 minutes, and the complete experiment including questionnaires, lasted 45 minutes on average.

### 4.4 COLLECTED DATA

For each trial and each subject, we recorded the completion time (in seconds) as well as the head position and orientation in the virtual world. This data allowed the computation of the speed (in $m.s^{-1}$) and the path deviation (in $m^2$) which is defined as the area between the path followed by the subject and the ideal path.

## 5. RESULTS

On the overall population, 64% preferred the joy pad. However, if we look only at the subjects who never played a FPS, the smartphone was preferred over the joy pad with 67%. The overall path deviation of the subject's with a smartphone was 27% higher than with a joy pad.

As we can see on the Figure 4 (left), gamepad users were walking in zigzag when they were not heading to the right direction. We can argue that joystick is too much sensitive to do a precise task. On the opposite, the smartphone had the smoothest curves but was often offset. It can be explained by the fact that Space Scrolling doesn't provide a way to do lateral translations. For both metaphors, none of the participants took advantage of the fact that turning the device adjusts the direction of translation, and only a few turned on themselves to rotate, using the rotation controls only to avoid the missing screen.

On the figure 4 (right), we can see the curves of speed showing the different behaviors of the two metaphors. On the one hand, the joypad induces a nearly constant speed which can be easily adjusted. While on the other hand, the Space Scrolling metaphor on the smartphone induces frequents peaks of speed.

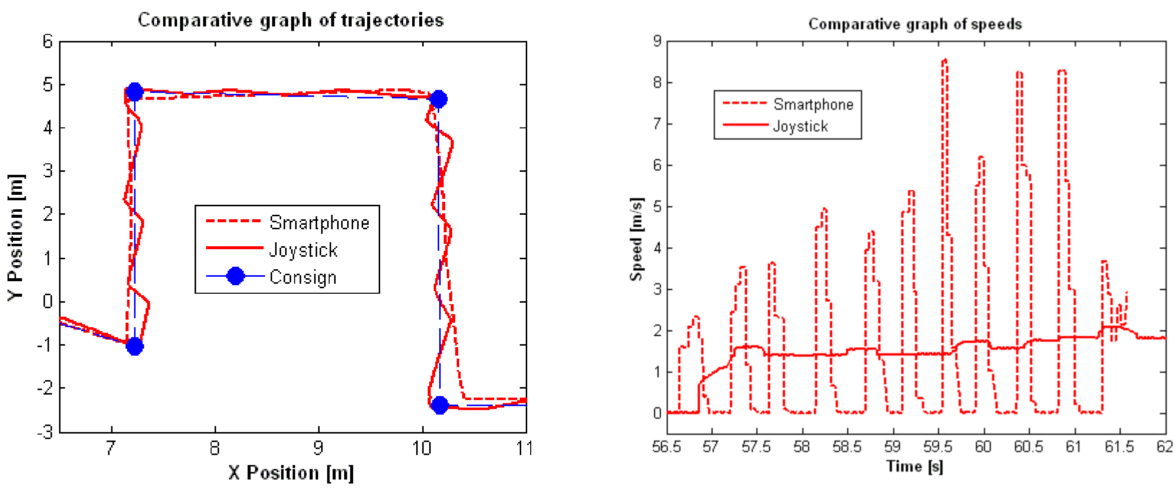


Figure 4 : Comparative graph of trajectories (left) and comparative graph of speed (right)

## 6. DISCUSSION

Thanks to the tracking body placed on the smartphone, it was theoretically possible to make a lateral displacement; nevertheless, subjects never used this feature even if they were taught to during the familiarization phase. This weakness was decisive for the accuracy computation of the Space Scrolling metaphor, we thought about what we could modify to improve it. We originally implemented a control with only one finger and one hand because we wanted to keep it simple. However, novice users were mainly using their both hands, and some even tried to use 2 fingers. That let us think that we should modify the way Space Scrolling works. Using the one finger touch for moving in any directions and for the rotation: the famous 2 fingers move pinch-to-rotate.

Also, we noticed that for both metaphors, people became sick during rotations, especially for people who never played any FPS video game. Cyber sickness or simulation sickness is a major problem of virtual reality and has already been frequently reported and analyzed in the literature [14], [15]. Two main user conditions may induce simulation sickness in CAVEs: while the user is driving or moving using control devices, especially when rotating because of the discrepancy between visual and vestibular perception of the movement. This latter may be significantly worsening with a too large transport delay, the delay between actions and theirs results [17], [18]. This has to be taken in consideration for any control device design for a friendly and efficient locomotion metaphor without generating simulation sickness.

Our results show that novice users prefer the proposed nomad device, probably as an already known device with interaction metaphors similar of theirs every days uses. On the other hand, with the first implemented version, frequent VR user or gamer may be more efficient in controlling trajectory and moving to the targeted position. For industrial user it is too early to state which type of devices and/or metaphors would be preferred, especially as it will be easy to complete our space scrolling metaphor on nomad devices with a precision selection scroll wheel to allow a very precise positioning.

To avoid cyber sickness it should be possible to segment displacement orientation and avoid direct rotations implementing a distinct rotation function, whatever control device is used. Further evaluations of the existing metaphors and theirs updated versions should be carried out with new protocols to take into consideration a modified version of our metaphor for rotations. According to future assessment, the first implementation of this new metaphor in current industrial software versions used at Renault will be carried for SCANeR © Studio [19] used with Catia from Dassault Systems, merging virtual mockup data with virtual environment thanks to Techviz Fusion. First use-cases will concern exterior vehicle design and lightning [20].

## 7. CONCLUSION

Our goal was to design a metaphor that would allow novices of virtual reality and/or videogames to navigate easily in a virtual world with a single hand. We have introduced Space scrolling, a nomad device tool for egocentric displacement and we compared it with traditional gamepad First Person navigation. A first evaluation showed that VR and video games novices were inclined to prefer this new technique.

Nomad devices being largely in use, much larger than joystick or whatever traditional VR device, they should be at least an efficient, user friendly and affordable choice for interactions in a virtual environments. Further evaluations of the existing metaphors and theirs updated versions in light of the presented results will be carried out in the next future.

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