Nomad Devices for Interactions in Immersive Virtual Environments

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ABSTRACT

Renault is currently setting up a new CAVE™, a 5 rear-projected wall virtual reality room with a combined 3D resolution of 100 Mpixels, distributed over sixteen 4k projectors and two 2k projector as well as an additional 3D HD collaborative powerwall.

Renault's CAVE™ aims at answering needs of the various vehicle conception steps [1]. Starting from vehicle Design, through the subsequent Engineering steps, Ergonomic evaluation and perceived quality control, Renault has built up a list of use-cases and carried out an early software evaluation in the four sided CAVE™ of Institute Image, called MOVE. One goal of the project is to study interactions in a CAVE™, especially with nomad devices such as IPhone or IPad to manipulate virtual objects and to develop visualization possibilities. Inspired by nomad devices current uses (multi-touch gestures, IPhone UI look'n'feel and AR applications), we have implemented an early feature set taking advantage of these popular input devices. In this paper, we present its performance through measurement data collected in our test platform, a 4-sided homemade low-cost virtual reality room, powered by ultra-short-range and standard HD home projectors.

Keywords: Interaction technique, navigation technique, virtual reality, augmented reality, nomad devices, immersive room, simulation, CAVE™

1.   INTRODUCTION

Renault's CAVE™ project, called IRIS (Immersive Room and Interactive System), aims at answering needs of different steps of vehicle design. Starting from vehicle architecture through the subsequent phases of design, ergonomic and perceived quality control to production, Renault has built up a list of use-cases, among them: evaluation of design and perceived quality, HMI, vision through windshield, cockpit 'ambiance' lighting.

Figure 1 : Institute Image's platform MOVE (left) and Renault's current CAVE (right)

Renault's Technical Center for Simulation is currently using a number of software solutions:

- SCANeR: a driving simulation software package with an all-in-one concept, from scene composition through scenario design to simulation and analysis [2, 3], initially developed by Renault and now distributed by Oktal, a simulation software and system provider.
- TechViz Fusion: a solution to enable to run multiple 3D applications together without data conversion displayed in a Virtual Reality system, provided by Techviz.
- Catia V5/V6: a CAD software from Dassault Systems, a 3D and PLM (Product Lifecycle Management) software company.

Renault also carried out an early software evaluation in the four sided CAVE™ of Institute Image, called MOVE. Pursuant to this evaluation, Renault has defined the user specifications for interactions in IRIS, requiring a driving station for HMI and vision evaluation as well as an *intuitive device and software for virtual object selection and manipulation* especially for design and perceived quality control operations.

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:

- Virtual mirror: a smartphone becomes a mirror one can hold in the palm of his hand and manipulate in a very intuitive manner.
- Navigation controller: we introduce a new navigation paradigm using a 2 6DOF tracker and tactile inputs of a nomad device.
- Window of annotation: a tablet becomes an AR-style window which allows to annotate the virtual world.
- Magical lens: The tablet becomes a lens which reveals hidden information, such as annotations or a 3D model superimposed to the one displayed in the virtual world for comparison.
- Camera: In the virtual world, the tablet becomes a virtual camera, just like in the real world.

In this paper, we present these features and corresponding implementation in Renault's test platform.

2. SELECTION AND MANIPULATION TECHNIQUES

2.1 Existing techniques

Selection and manipulation in a virtual environment are two of the most fundamentals interactions forms. While the area has been highly documented, a short overview of existing techniques is given in this section.

2.1.1 Ray based techniques

Ray casting [4] is one of the most popular techniques and has been declined in several versions. The user directs a virtual LASER beam at an object with his hand or a wand and triggers the selection by holding a button. The object is then attached to the beam and can be manipulated until the button is released. While closest operations are easy to perform, the farther, the harder. Indeed, beam's length amplifies pointing imprecision. Moreover, translations along the beam are limited as well as rotations other than around the beam, which can be solved through the use of additional buttons [5].

In PRISM [6], the ray's precision is improved by scaling its motions depending on their speed. Therefore, slow motions are scaled down to increase precision, while fast motions are used to cancel the induced offset and realign the ray with the wand.

The friction surfaces technique [7] differs from ray casting in that the ray behaves differently when intersecting with 2D windows floating in 3D space. In this case, its motions are scaled down to increase its accuracy. In contrast with PRISM, the ray is then curved to provide visual feedback for both ray's start and end.

Spotlight [8] is a ray-casting alternative version which solves the imprecision issues by making use of a selection's cone instead of a ray. One drawback is that several objects may simultaneously fall in the cone.

Shadow cone [9] is an extension of Flashlight which solves the discrimination's problem in selection but still allows multiple objects selection at a time. The user holds the button, moves the cone and releases it. Then, only objects that stayed in the cone all along are selected.

The aperture [10] is a variation of flashlight in which the user can modify the aperture of the cone. The user holds a wand with a virtual disk always oriented to the user's dominant eye on top of it. When pressing the selection

button, every object contained in the cone defined by the eye and the disk is selected. Thus, the user can vary the aperture of the cone by moving the wand near or away.

2.1.2 Virtual hand based techniques

The virtual hand technique [4] allows one to directly grab an object with his hands and manipulating it as one would do in the real world. While very efficient for virtual objects manipulations within arm's reach, long range manipulations are impossible or require a travel technique.

The Go-Go technique [11] addresses this problem by allowing the user to expand his arm so as to reach distant objects. When the real hand is close to the body, the virtual one behaves like the original version, while when the real hand stretches, the virtual one moves at an exponential rate. Even though this allows quickly moving an object, long range manipulations remains inaccurate. To overcome this problem, Bowman implemented several variations of the Go-Go technique [5] changing the way to control the extension of the arm.

Grabbing the air [12] extends the virtual hand metaphor with the use of the two hands. The user can now scale or rotate an object by grabbing it with both hands. This looks like a 3D version of the well-known *'pinch to zoom and rotate'* multi-touch gesture.

2.1.3 Hybrid techniques

HOMER [5] is a technique that combines the strength of both ray-casting and virtual hand techniques. The selection is done by a classic ray-casting, and then a virtual hand appears holding the pointed object so the user can manipulate it naturally. The virtual/real arm extension ratio is then locked until the user releases the object. As for Go-Go technique, there are many variations of the arm's extension control.

The image plane technique [13] determines the direction of the ray with 2 points, the head and the hand, thus providing a better precision for long-range manipulations. In order to select an object, the user pinches the 2D projection of an object in his image plane between his index finger and thumb. The object is then instantaneously translated in the user's hand.

Scaled-world grab [14] is an alternative version of the image plane technique; with the difference that when an object is selected, the whole world is downscaled to ensure that the object matches the user's hand's position. When the button is released, the world is scaled back to normal, but the position of the user may have changed as a consequence of the hand and object alignment constraint.

The voodoo doll [15] extends the image plane technique with the use of both hands. It relies on a study showing that the non-dominant hand act as a referential for the other one. At first, the user selects an object by pinching his projection with the non-dominant hand, and then a copy of it is scaled at a suitable size for manipulations (half a meter) and placed in the user's hand. The second selection is done with the dominant hand, and this time the created copy is scaled with the same ratio as the other one. The user can then position the copies relative to each other and the transformation between them only affects the original version of the copy held in the dominant hand.

2.1.4 Selection and manipulation aid

The dynamic magnifying glass [16] is a technique to be used in conjunction with any selection and manipulation technique and which solves the long-range manipulations problems. The idea is to zoom an area of interest by locally stretching 3D space, then use a selection or manipulation technique such as ray-casting or virtual hand. So as to zoom, the user just has to point a direction and hold zoom button.

In WIM (World in Miniature) [17], a miniature of the virtual world is standing in front of the user or held by him. As for the dynamic magnifying glass, the user can select and manipulate 3D objects with the usual selection and manipulation techniques. The miniature is synchronized with the virtual world and one can even move an object from one to the other. The main drawback is that the miniature's size may be too small for precise interactions.

2.2 Proposed new technique: Ray scrolling

While several selection and manipulation techniques already exist, the most intuitive and popular one remains ray-casting even if it is not sufficiently precise for remote manipulations and lack several degrees of freedom. Thereby we propose Ray Scrolling, an alternative version of ray casting, correcting these limitations by taking advantage of the use of a tracked Smartphone as input device. Selection of an object is done by a double tap gesture. Once selected, one of the missing rotations can be done by a horizontal scroll, while a vertical scroll will translate the object along the axis. Finally, we also support some additional two fingers gestures, thus pinching will zoom the object and scrolling vertically

with two fingers will perform the last rotation. A major advantage of this technique is that one finger is enough for most common manipulations tasks whilst the use of two fingers allows for more complex manipulations.

2.3 Implementation

To provide smooth translations of an object along the ray on a long distance, we added an inertia effect which is common on Smartphones.

At first, we allowed for simultaneous vertical and horizontal scroll gestures, but since thumb gestures are circular, simultaneous translations and rotations were too much confusing. Thus we locked scrolling orientations, meaning that the user can solely do rotation or translation separately and direction of scrolling is computed only after a certain distance traveled by finger. Also, the distance finger travels is scaled up so as to avoid the need of excessively repetitive gestures.

The reason we chose double tap for selection is that it allows for travelling with another technique while carrying an object. Besides Ray scrolling has been thought to be used in conjunction with our travel technique.

We tested our technique in a four sided test platform and on a Samsung Galaxy SIII with 6DOF optical tracking. Both were running Unity3D and communicating over Wifi.

3. TRAVEL TECHNIQUES

3.1 Existing techniques

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.

3.1.1 Walk based techniques

Redirected Walking [18] and Motion Compression [19] 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 [20] 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 [21] 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 [22] 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 [23] 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.

3.1.2 Metaphor based techniques

With Pen and tablet [24], 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 [17] 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 [11] 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 [25] 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 [12] 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 [26] allows the user to drive a virtual animal using reins. He can invoke the companion by joining his hands, drive using well known reins orders (left, right, faster, slower, stop) and dismiss it by crossing his hands.

3.2 Proposed new technique: 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 [27] 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.

3.3 Implementation

Again, we locked scrolling orientations because going straight was too much difficult.
Also, to provide smooth travels on longer distance and thus to limit simulator sickness, we added an inertia effect.
We only have implemented a 2D version of the technique which means the altitude is constrained by the terrain but it could be extended to provide navigation in every direction of space by pointing up or down.

4. USE CASES AND PROPOSITIONS

4.1 Use cases

Renault's new CAVE™ aims at answering more than 50 use cases. Among them, some require specifically interactions:

- Easy navigation in the virtual environment so as to perform perceived quality check from different points of view.
- Comparison with a concurrent vehicle while varying different simulation parameters such as ambient light or scenery.
- Perceived quality checks even in tight spaces
- Retro conception by easily modifying the digital vehicle geometry or materials in real-time.
- Annotations with text or voice to capitalize knowledge.
- Driving to provide a context for the review. Of course, Renault uses specific driving simulation tools [28], but here the aim is to provide an interactive path traveling for full visualization of the vehicle from the outside to the inside.

4.1.1 Annotations

Annotation of vehicle's part is of major importance because it is a good way to capitalize knowledge gained during the design review [29]. Most techniques uses ray-casting to define a point to be annotated, none of which propose an easy text input technique. For this purpose, we propose to use the virtual keyboard of the Smartphone as it's a relatively efficient and portable input device.

4.1.2 Virtual camera

The virtual camera is a transposition of the Smartphone's camera in the virtual world. The user can take pictures of virtual content as he is used to do in real world with his Smartphone and then annotate it. We could even think of a mode that would start a deported high-fidelity rendering.

4.1.3 Virtual mirror

With the virtual mirror, a Smartphone becomes a mirror one can hold in the palm of his hand and manipulate in a very intuitive manner. This metaphor aims at providing a tool for perceived quality. Thus, for example the user could verify the quality behind the steering wheel from the driving seat.

4.1.4 Magical lens

The tablet becomes a lens who reveals hidden information, such as annotations or a 3D model superimposed to the one displayed in the virtual world for comparison.

4.2 Implementation

These metaphors have not yet been implemented, but having a good-looking and fast 3D view on the Smartphone with low latency will surely be a major challenge.

5. DISCUSSION AND CONCLUSION

In this paper we have presented innovative interaction techniques. It includes a new set of intuitive interaction tools, such as space scrolling, magical lens and virtual camera. Space scrolling, an easy nomad device tool for egocentric displacement together with ray scrolling, an enhanced version of ray casting has already been implemented. Both have been integrated in a 4 sided virtual environment test platform, using industrial use cases in the domains of engineering design and perceived quality.

Future work will involve comparative studies in Renault's new 5 16Mpixel sided real-time CAVE™, IRIS and in the 4-sided virtual environment display device of Institut Image of Arts et Métiers ParisTech, MOVE. Moreover, magical lens and virtual camera tools will also be implemented and tested in psycho-physical experiments.

Pursuant to these following assessment experimentations, an early integration of these interactions for the evaluation of an industrial deployment within the software tools deployed at Renault will be planned.

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