Camera Viewpoint Control with the Interaction Table

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ABSTRACT

The Interaction Table has initially been developed to answer the question: "how to allow several participants to quickly and easily modify the camera viewpoint when facing large immersive displays?" The Interaction Table is a 6 DOF device mixing iotonic and isometric information. A fixed tablet on the top enables the use of 2D techniques while keeping immersed in the 3D environment. We have developed several interaction techniques to control the camera viewpoint using the Interaction Table. These techniques are based on scene manipulation, direct camera viewpoint manipulation, and target selection. The appropriate technique to choose depends on the task to be accomplished. Early tests have shown that the device can be used for an efficient camera viewpoint control after a very short learning period.

KEYWORDS: Input device, Interaction techniques

1. Introduction

Controlling the camera viewpoint is probably the main task users have to perform when dealing with 3D interactive graphics. The appropriate way to control the viewpoint depends on the type of application. For example, when working on virtual prototypes, engineers usually need to see their 3D models from different exterior viewpoints whereas architects mainly have to travel inside their virtual buildings to see them before they are constructed.

The viewpoint control is generally performed by interaction techniques composed of physical devices and transfer functions. For example, desktop applications usually permit the manipulation of the camera viewpoint by interpreting the screen coordinates of the mouse, whereas Head Mounted Displays (HMD) are usually coupled with head tracking in order to modify the camera viewpoint according to the position of the user's head.

Large immersive displays allow several participants to be located in the same physical space. New constraints for interaction are coming up with such systems. Interfaces used with desktop displays or HMD are not always well adapted to large displays. For example, the size of the screen as well as the use of stereo viewing make mice ineffective, and the fact that each participant should be able to modify the viewpoint forbids the use of head tracking.

Therefore, we ask ourselves the question: "how to allow several participants to quickly and easily modify the camera viewpoint when facing large immersive displays". To answer this question, we have developed a new device called the Interaction Table [7]. Many interaction techniques can be used with the Interaction Table to accomplish different interaction tasks (navigation, manipulation, selection, system control). In this paper, we focus on the control of the camera viewpoint.

Section 2 describes some standard existing input devices as well as the Interaction Table. We present in section 3 the interaction techniques we have developed. In section 4, we provide general remarks about the use of the Interaction Table and discuss the interaction techniques we developed. Finally, in section 5, we conclude and give directions to future work.

2. Input Devices

2.1. Existing devices

There is a lack of standard input devices allowing several participants to efficiently control the camera viewpoint in immersive large display environments. Generally, either desktop devices (e.g. mice, isometric devices) or immersive devices (e.g. gloves, isotonic devices) are used. In the following, we present some existing approaches and their limitations.

Laser pointers have been presented to adapt the mouse to large displays, see for example [9]. The main disadvantage of laser pointers and mouse-based approaches in general is the limitation to 2 degrees of freedom (DOF) making some 3D interaction tasks, as for example the viewpoint control, hard to perform. Moreover, the presence of a cursor on the screen disturbs the immersive feeling, and stereoscopic visualization becomes problematic.

As an alternative, Personal Digital Assistants (PDA) can be used to command the system [14]. PDAs allow users to move in front of the screen while keeping immersed in the environment. The main disadvantage of this approach is that the interaction techniques are still based only on 2D input. Moreover, a constraint is that the users have to carry the device.

Isometric devices, as for example the Spacemouse and the Spaceball, allow users to control 6 DOF at the same time. Hence, users can control the viewpoint more intuitively in 6 DOF virtual worlds. The main problem of these devices is that hours of practice are required before being efficiently used, as has been experienced by Zhai [15].

We believe that isotonic devices, as for example the Wand and the electromagnetic trackers in general, are mainly adapted to one head-tracked user. When facing large screens, the camera viewpoint is common to all co-located users, hence, the interaction techniques to be used must not depend on the position of one user. For example, *ray casting* with a virtual pointer is not possible. So, the interest of immersive devices is reduced, and their disadvantages are particularly annoying when facing a large screen. Among these disadvantages, we state the device acquisition problem, the lack of location persistence, and the fatigue.

Some devices are designed to perform "natural'" travel metaphors. For example, Bougila et al. [2] propose to use an omni-directional locomotion interface to simulate human walk. This approach has the advantage of exploiting human skills, which is intuitive for users. However, these kind of interfaces are dedicated to one specific metaphor and can therefore be used in only one particular context.

Finally, Bolt [1] introduced speech and gesture recognition to allow users to feel free in the environment. One of the disadvantages of this approach is that a language has to be learned in order to interact with the 3D world.

2.2. The Interaction Table

The Interaction Table looks like a table. Our current prototype is about one meter height and sixty centimeters wide (Figure 1).

Figure 1: The Interation Table prototype

The tabletop can be oriented in space thanks to three nested elements. The tabletop is attached to the center of a crossbar and can rotate around its normal direction. This rotation axis is called *Yaw*. The extremities of the crossbar are attached to a ring. The tabletop can rotate around the axis defined by the crossbar attachment points. This rotation axis is called *Roll*. The ring is attached to a base. The tabletop can rotate around the axis defined by the ring attachment points. This rotation axis is called *Pitch*. Angular sensors recover the rotation angles from each of the three axes. Users can orient the tabletop in space without any resistance, this corresponds to an isotonic resistance mode. Figure 2 shows the rotation axis of the Interaction Table.

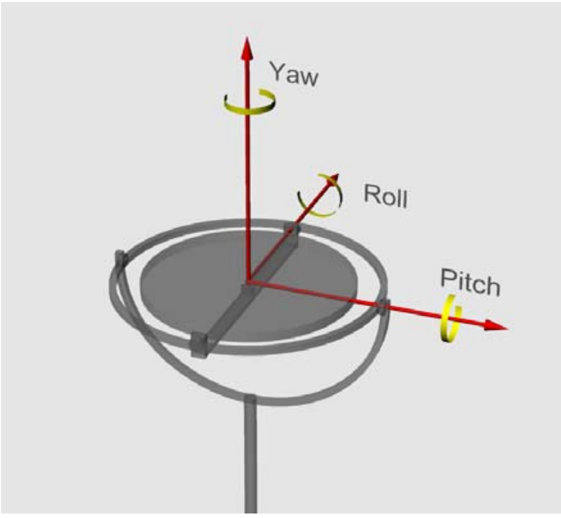


Figure 2: The Interaction Table rotation axis

The tabletop is equipped with a potentiometer allowing to recover the forces applied on it in the three perpendicular directions. In a given orientation, users can push on tabletop in any direction without displacing it, this corresponds to an isometric resistance mode.

Consequently, the Interaction Table is a 6 DOF device mixing isotonic and isometric resistance modes. The tabletop can rotate infinitely around its rotation axes. Applied forces to the tabletop are recovered in the frame given by the *Yaw*, *Pitch*, and *Roll* rotation angles.

In addition, a standard tablet is fixed on the tabletop. It allows to precisely recover the position of a pen on it. Two buttons are fixed on the left side of the Interaction Table.

The physical nature of the Interaction Table offers some substantial advantages:

- Its free standing and location persistence properties make it shareable by all co-located users.
- It is non-constraining and allows an effortless usage.
- The DOF can either be controlled independently or at the same time.
- The table top gives the user a passive haptic feedback.
- It is accurate and responds within a short time lag.

The Interaction Table is located in front of the screen. During a session, the user who wants to modify the camera viewpoint takes the control of the Interaction Table, standing in front of it, without passing by a time-consuming equipment stage and without carrying anything.

3. Interaction Techniques

A number of interaction techniques have been developed to control the camera viewpoint [3, 8, 11, 13]. This section describes some interaction techniques we have developed for viewpoint control with the Interaction Table. These techniques are based on scene manipulation, direct camera viewpoint manipulation, and target selection.

3.1. Scene manipulation techniques

Scene manipulation with the Interaction Table can be performed by two techniques based on the *scene in hand* metaphor.

Scene in hand technique

The first technique we developed directly implements the scene in hand metaphor. The metaphor consists in modifying the viewpoint of a 3D scene by moving the whole scene, as it is done with the Cubic Mouse [5]. By attaching the movements of the Interaction Table to the movements of the 3D world, users hold the scene by the table top. The similar orientation of both the table top and the virtual scene gives users a passive haptic feedback and ensures coherent stimuli response, i.e. the scene can be moved in a specific direction by simply pushing the table top in this direction. Thanks to the mechanical construction of the Interaction Table, users can rotate the virtual scene infinitely without clutch systems and without twisting one's arm.

Targeted scene in hand technique

A limitation of the scene in hand metaphor is that transformations are applied in world frame, however, sometimes it could be better to apply transformations in another frame. For this reason, we have developed a new technique we call the *targeted scene in hand* technique. After incorporating a semitransparent 3D model representing the physical table top, the *virtual table top*, into the scene, the technique consists of two steps: first, moving the virtual table top in the virtual space, and second, by pressing a button, attaching the 3D scene to the virtual table top. Once attached, the scene can be turned around the center of the virtual table top as illustrated in Figure 3. A second button is used to either display the virtual table top or not. When the virtual table top is displayed, the user sees the center of rotation, which gives a visual feedback. Both the virtual and the physical table top always have the same orientation.

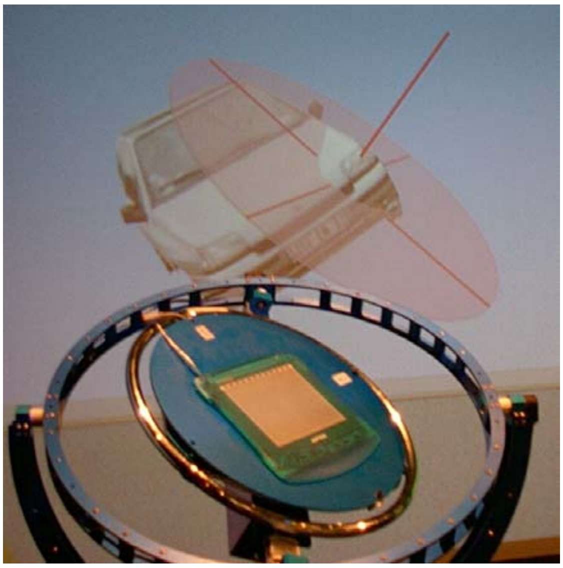


Figure 3: Targeted scene in hand technique

3.2. Direct camera viewpoint manipulation techniques

In this section, we show how the 6 DOF of the Interaction Table can be used to directly control the camera viewpoint.

Eyeball in hand technique

The *eyeball in hand* metaphor was implemented by attaching the movements of the camera viewpoint to the movements of the Interaction Table. Translations are determined by a rate control process, i.e. while a pressure is applied to the table top the viewpoint is translated. The orientation of the viewpoint is determined by a position control process, i.e. when a ten degree rotation angle around an axis is applied to the table top, a ten degree rotation angle around the corresponding axis is applied to the viewpoint in the virtual scene. Pushing the table top in the direction of the screen induces a forward movement in the virtual environment, regardless of the orientation of the table top.

Vehicle control technique

The Interaction Table can be used as a 3D steering wheel to control trajectories. This is done by associating a rate control process to the *yaw* component of the table top making it possible to steer to new directions by applying small rotations. The velocity of the yaw rotation is proportional to the yaw angle of the Interaction Table and the velocity of translations is proportional to the amount of pression applied by the user. Hence, the user can *fly* in the world. A *drive* technique has also been implemented by constraining the DOF. Figure 4 shows the Interaction Table used to fly over a virtual city.

Figure 4: Using the Interaction Table to fly over a virtual city.

3.3. Target selection techniques

Some interaction techniques consist in selecting the endpoint of a trajectory. A famous example of this kind of techniques has been developed by Mackinlay et al. [8]. We have developed four *target selection* techniques for the Interaction Table. Figure 5 shows an overview of the different target selection techniques.

Item selection technique

The fixed tablet on the table top facilitates the use of widget-based interfaces, where items are mapped on the virtual table top (see Figure 5a). The users can position the widget-based interface anywhere in the virtual space and select the items with the pen on the tablet. In this way, users can select targets, and modify parameters as for example the velocity or the field of view.

Object selection technique

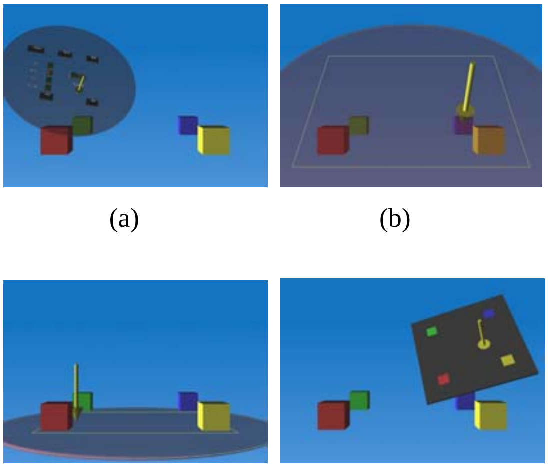
In order to directly select targets in the 3D scene, we use the virtual top as a filter through which the objects are seen. Users position the virtual table top between the camera and the objects and then choose an object by selecting its projection on the virtual table top (see Figure 5b). We call this technique *object selection* technique. It is similar to classical mouse-based selection techniques where an object is selected from its projection on the screen. The advantage of our approach is that stereo viewing can be unrestrictedly used. Furthermore, no disturbing cursor reminds that the scene is displayed on a screen.

Point selection technique

The *point selection* technique we have developed consists in moving the viewpoint to a point which has been selected on the virtual table top (see Figure 5c). This point doesn't have to belong to any object of the scene. The orientation of the viewpoint at its target point corresponds to the orientation of the table top. First, users position their landing ground by moving the virtual table top in the virtual space, and then, land on it by using the pen on the table.

Selection on map technique

The last technique we have developed for the Interaction Table, the *selection on map* technique, is similar to the technique used by Bowman et al. [4] based on the *pen and tablet* metaphor. The principle is to select a target location on a 2D map representing the 3D scene (see Figure 5d). Users position the 2D map in the virtual space by means of the table top. By using the pen on the physical table top, users can easily select targets in the scene.



(a) (b) (c) (d)

Figure 5: Target selection techniques: (a) Item selection. (b) Object selection. (c) Point selection. (d) Selection on map.

4. Discussion

Our experience with the Interaction Table as well as the first user comments allow us to make a first qualitative evaluation of the device for the camera viewpoint control.

4.1. General remarks

Users are really enthusiastic when using the Interaction Table for the first time. They manage to control the camera viewpoint after a very short learning period. We believe that the Interaction Table is easy to use for the following reasons.

First, each of the 6 DOF can be controlled independently. Given that humans must mentally decompose an absolute rotation in a sequence of simple rotations [10], the contribution of the Interaction Table can be easily understood. This characteristic is the fundamental difference of the Interaction Table to 6 DOF isometric devices.

Moreover, the orientation of the physical table top gives a strong mark to the users allowing them not to be disoriented. For example, when using the *scene in hand* technique, moving the world to its initial position can simply be done by moving the Interaction Table to its initial state. When using the *fly* technique, users can see the world in a horizontal plane by simply moving the table top to a horizontal plane.

Concerning translations, users find the system intuitive as the displacements were performed according to the orientation of the table top. Moreover, users find it pleasant to operate with a physical object they hold.

Finally, the use of the pen on the tablet with the visual feedback on the virtual table top doesn't cause any difficulties. The movements of the users are accurate and coordinated. Their performance seems to be close to the performance of people using tablets with a feedback by a cursor on a classical screen.

4.2. Choice of the technique

The choice of the technique to be used depends on the task to be accomplished (e.g. examine, discover, search).

Scene manipulation techniques

The *scene in hand* technique is particularly well adapted to review processes, where the main task is to quickly see a 3D scene from different viewpoints. The 3D scene should be a world frame centered object that users see from the outside. This configuration is similar to the default mode of classical 3D viewers.

The *targeted scene in hand* technique is useful when users want to focus on specific parts of an object. For example, when dealing with a car model, users are able to examine the whole object and can then focus on particular interests like the wheel or the headlights.

Direct camera manipulation techniques

Concerning interaction techniques based on direct camera manipulation, the *eyeball in hand* technique is efficient when the task is to examine the interior of objects (e.g. cars, buildings) because the rotations provided by the Interaction Table are directly mapped to the camera viewpoint.

When the task is to explore large zones (e.g. virtual cities, landscapes) the eyeball in hand technique is not efficient because users must turn the table top, then push it to go forward, release it, then turn it again, and so on. In this case, the *vehicle control* techniques should be preferred allowing the users to hold the table top without releasing it.

Target selection techniques

The main interest of the target selection techniques is to travel in space in accurate and smooth trajectories. Once again, the choice of the technique to be used depends on the application.

The *item selection* technique is appropriate in applications where many objects are referenced. For example, during a virtual prototyping process, it is interesting to directly position the viewpoint to face a specific object.

The *object selection* technique allows the users to directly select the objects they see.

The main advantage of the *point selection* technique is that the selected point doesn't have to belong to any of the objects. Moreover, because the orientation of the viewpoint is given by the orientation of the table top, coming back is possible. The coming back process is often a problem using target selection techniques as has been stated in [6].

The use of the *selection on map* technique is appropriate in a known environment. It helps users for navigation tasks.

All the four techniques described above can be used with stereo viewing and within the virtual space. The immersive feeling is not disturbed as neither cursors nor menus are displayed on the screen. From this point of view, the Interaction Table differs from classical pointing devices. Furthermore, contrary to the majority of immersive devices, users keep a physical support in the environment to interact with.

5. Conclusions

The Interaction Table is a 6 DOF device allowing users to quickly and easily interact with 3D interactive graphics displayed on large screens. We have described several interaction techniques allowing the camera viewpoint control. The interaction techniques to be used depend on the task to be accomplished. Some of them can be coupled together (e.g. point selection with eyeball in hand), but as a general rule, the different techniques should not be mixed in the same application in order not to disturb the users.

The Interaction Table has initially been designed for the scene in hand technique, but we have seen that other techniques can be used, particularly thanks to the physical table top. We believe that many other techniques can be used with the Interaction Table. For example, we plan to implement techniques based on Magic Lenses [12] as for example the Magic Mirror [6]. We also plan to use the Interaction Table for the definition of complex, accurate trajectories while keeping immersed in a virtual environment.

Acknowledgments

We would like to thank the Laboratory of Mechanics of Bordeaux University (LMP) which has conceived the physical prototype of the Interaction Table.

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