

"two - 4 - six" - A Handheld Device for 3D-Presentations

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ABSTRACT

We introduce a novel one-handed input device for 3D interaction. Its functionality is based on a classification and valuation of used degrees of freedom in common VR applications like Architecture Review, Virtual Museums or Games, where navigation is the predominant interaction mode. The two - 4 - six device allows efficient and comfortable control of six degrees of freedom with the fingertips. The device contains an additional gyroscopic rotation tracking sensor to indicate directions for movement or selection.

CR Categories: H. Information Systems

H.5 INFORMATION INTERFACES AND PRESENTATION

H.5.2 User Interfaces

H.5.2.3 Ergonomics, Input devices and strategies, Interaction styles, Prototyping, Theory and methods, User-centered design

Additional Keywords: HCI, human factors, 6DOF, interaction, input device, industrial design, virtual reality, handheld, pointer, presenter

1. INTRODUCTION

Navigation, selection and manipulation are important tasks in virtual environments, which are often controlled by input devices such as wands and gloves. These interfaces are based on the use of complex technologies like 6-DOF tracking but they are not particularly designed to meet the requirements for these tasks.

We designed an input device for presentation tasks in three-dimensional environments. Our design is motivated by a task analysis and provides the required degrees of freedom in the appropriate combinations. We built a prototype of our device using rapid prototyping techniques and integrated it into a presentation application. First experiences with the device confirm that the chosen design works and it is easy to use. The "two - 4 - six" device is a simple, low cost 3D-interface, that allows a broader use of interactive 3D-graphics for teaching and presentation (Fig. 1).

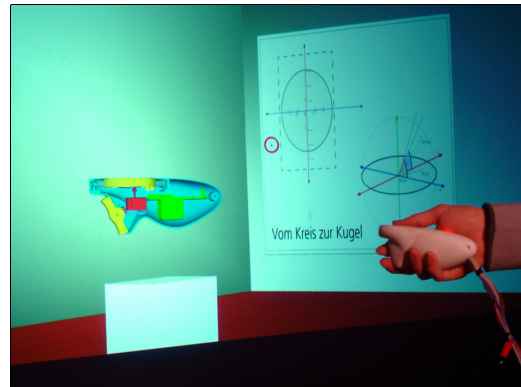


Figure 1: Using "two - 4 - six" in a 3D-presentation

2. RELATED WORK

2.1 Multidimensional Interaction

The design of interaction devices mainly consists of decisions for appropriate sensors and their sensible and ergonomic arrangement. According to Foley et al. [3], there are six general transactions to be supported by input devices: selection, positioning, orientation, ink, text and value. Depending on the application, not all of them need to be controlled with the same device. For a 3D presentation-task object-selection, positioning and orientation of the view and virtual objects are the most important interactions. For finding compatible sensors, their technical description is not very helpful. To facilitate the design process, Bill Buxton introduced a pattern for the categorization of sensor devices with respect to the human motor/sensor system [1]. This taxonomy shows the sensed property (force, motion or position), the number of dimensions and whether the device works mechanically or by a touch-sensing mechanism. It further provides information about different devices, which use comparable motor control for their operation.

In 1990 Card et al. [2] introduced another classification approach that allows to distinguish between linear and rotary sensors and shows the sensed axes. Similarly to Buxton, the sensed property is a main distinction in their scheme. They neither differentiate between touch-sensitive and mechanical sensors, nor do they consider the human motor activity, but whether a sensor works discrete or continuously is apparent in their tables. Zhai investigated the relation between the sensed property and the used transfer function [10]. He showed that isotonic sensors work better with position control techniques whereas elastic and isometric sensors should be used with rate control. Travel tasks are mostly controlled by rate control, which provides smoother movement and causes less fatigue. With respect to Zhai's findings, elastic devices should work better for such tasks than isotonic ones.

Much effort has been spent on trying to categorize sensor devices. The results surely help to understand sensor technology, but until

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these categories are not related to certain task requirements they also complicate the design process. In 1994 Jacob et al. [6] proposed to consider the importance of human perception while designing an interface. According to them, simultaneously available DOF of the input device should be compatible to the perceptual structure and integral attributes of a task. For example: sliding along the image plane is a 2DOF translation. Mapping this task to the translational movement of a common 2D computer mouse perfectly complies to the task's perceptual structure. They further described differences in the perception of similar tasks. Object manipulation can therefore be divided into the coarsely controlled "ballistic phase" and the fine-tuning during the "closed loop phase". These different task phases could be supported by possibly different sensors, which leads to the suggestion that redundant DOF could improve the effectiveness of a device.

2.2 Handheld Devices

A variety of 6-DOF handheld devices is commercially available: The Polhemus Stylus [14] is a pen-shaped device containing a 6-DOF tracking sensor and a button. The Ascension-Tech Wanda [12] is a 6-DOF tracked handle, equipped with an elastic 2-DOF Joystick. Both use an electromagnetic tracking system. A.R.T. offers a 6-DOF joystick using an optical tracking system [11]. Furthermore there are non-commercial 6-DOF handheld devices: The "Bat" consists of an electro-magnetic tracking sensor, a button, and a handle [9]. The Fball or Fingerball is a ball-shaped input device containing an electro-magnetic tracking sensor [10]. This isotonic device is designed to be rolled with the fingertips to support dexterous rotational input. The Cubic Mouse is a cube-shaped box with three rods passing through it [4]. The 6-DOF tracked box is held with the non-dominant hand, whereas the rods can be pushed, pulled, and twisted with the dominant hand to support object manipulation.

Mainly based on the tracking of position and rotation in 3D-space, these devices provide symmetric motion control for all axes. With respect to the perceptual structure of certain tasks, this symmetry may be inadequate. Especially travel tasks could be facilitated with appropriate controllers for preferred directions. The Wanda, for example, offers a joystick for travel along a pointing direction. Experiments [5] with pointing devices for 3D-manipulation showed that a 2-DOF rotation tracker like the commercially available Gyromouse [13], equipped with an additional adjustment sensor to control movement in depth, works also well for rough object positioning. For fine-tuning, further controllers seem to be necessary.

3. DESCRIPTION OF THE INTERFACE

3.1 Motivation for the sensor arrangement for our device

The design of interfaces to control movement in three dimensions highly influences the usability of most VR-applications. To provide intuitive interaction within those 3D environments, we focus on three main topics:

1. The observation of human interaction with the real world – gestures, grips, perception, ergonomics, ...
2. The development of sensors and low level interfaces to record those interactions as input for applications – trackers, joysticks, buttons, device drivers ...
3. The transfer function: the interpretation of these inputs as interactions in virtual environments – device drivers, application software, GUI, ...

3D interactions do not need to accurately imitate real world behaviour, since the computer allows us to overcome the limitations of the physical world. A general guideline for direct manipulation in computer applications was introduced in 1983 by Ben Shneiderman[7].

For object selection, even in 3D, the use of a 2D-cursor is a very intuitive and commonly used technique. 2D-Pointing is also employed to indicate movement directions in navigation tasks. In both cases the common gesture of pointing with the index finger, the dominant hand, or an input device towards a certain object or into the desired direction is used.

Rotations with more than 360° are rarely required. The rotation angles mostly remain within a limited range. Thus direct positional control should not cause much need of clutching but allow adjustments of object orientations with higher precision.

Travel techniques might need to support the translation of the view over smaller and larger distances To avoid jolty movements caused by clutching, rate control seems to be more suitable.

To create a motion controller for the exploration and examination of virtual worlds, we studied movements performed in the real world for the same purpose. We assessed the significance of translations along lateral, longitudinal and vertical axis as well as rotations related to the same coordinate system (Fig.2). Rotations around the lateral axis will further be called "pitch"; around the longitudinal axis "roll" and around the vertical axis "head". We further classified the integrability and separability of these movements related to the user's perception based on the ideas of Jacob et al. [6]. Thus it was necessary to analyse the specific task of 3D exploration (navigation) and examination of objects (manipulation).

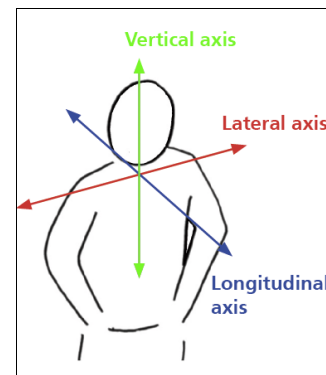


Figure 2: Coordinate system in relation to the human body

The way humans navigate through real environments is strongly influenced by a horizontal spatial structure (due to gravity) and the human mono-directional visual perception. Whether walking, flying or swimming, the most common concept of travel is a movement forward and backward in a selected direction. For steering along curves, the indicated direction is continuously adjustable. This can be performed in VR using a translation controller for one DOF combined with a simultaneously usable rotation controller for one or two DOF. To support travel metaphors like "walking" and "driving", which keep the viewpoint attached to a horizontal plane, the input device would be sufficiently equipped with a rotation sensor for the "head" direction. Free movement metaphors like "flying" additionally require "pitch" control. "Roll" is surely important for flight simulation, but can be neglected if the aim of the travel movement is nothing but the visual exploration of a virtual environment or simulation. In fact "roll" can even disturb a VR-experience,

because humans usually do not turn around the longitudinal axis while moving. "Head" seems to be the most important rotation direction as it is the common way to examine a surrounding by turning around the vertical axis. Thus, this rotation should be privileged in an appropriate input device. The controller should enable continuous "head"-rotation about at least 360°.

For changing the view onto an object in the virtual scene and to allow sliding moves along a vertical plane (e.g. a wall in an architecture model), translations along the lateral and vertical axis should be similarly supported by the device. In most cases they do not need to be used simultaneously with the longitudinal translation and may therefore be mapped onto a separate controller.

For a closer inspection of virtual objects, the interface should allow for their selection and manipulation. Using a 2D cursor, selection can easily be performed with a 2-DOF rotation tracker ("head", "pitch") to manipulate the cursor through a pointing gesture and a button to select the indicated object.

For the visual examination of these objects, the motion requirements in manipulation mode do not differ very much from those in navigation mode. Translations should be possible in all axes, but there may also be different controllers for sliding movements orthogonal to the viewing direction (lateral and vertical axis) and translation in depth to move the object closer or further away. Longitudinal displacements differ from lateral and vertical ones, as they are perpendicular to the view-plane. Somehow they are even more important for object examination, since the usual way of studying an object involves to bring it close. Once close-up they can easily be observed from all directions using rotation. For closer inspection, objects are mostly watched slightly from above and rotated around the vertical axis, just like being on a turntable. Again "head" seems to be most important for the task and should allow continuous rotation. "Pitch" permits to see the bottom of objects, which might be helpful but is often not as interesting as the other sides. "Roll" finally is not very useful for those presentation tasks, because it does not show any new face of the observed object.

3.2 Sensor configuration of the two-4-six device

To indicate a travel direction, manipulate a cursor or to move objects along the image-plane, the orientation of the device is tracked with an embedded gyroscopic sensor. It allows to perform any interaction based on pointing with the corresponding natural gesture (Fig. 3).



Figure 3: Using the gyroscopic rotation sensor to indicate directions

For rate control of translations, the device offers elastic sensors. A rocker-lever in the front part of the handle can be manipulated with the index and middle fingers controlling one DOF. The elastically suspended ring on top of the device offers two more DOF, manipulated with the thumb (Fig.4).

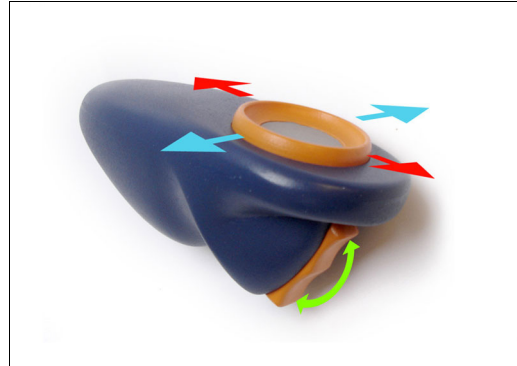


Figure 4: Elastic sensors for the input of translations

A touchpad is framed by that ring. It senses the absolute position of the fingertip and is used to control rotation around three axes (Fig. 5). This functionality is based on the Arcball rotation model by Ken Shoemake [8]. It causes less fatigue than the commonly used rotation of the whole device, which is furthermore significantly limited by rotational range of the human hand arm system.

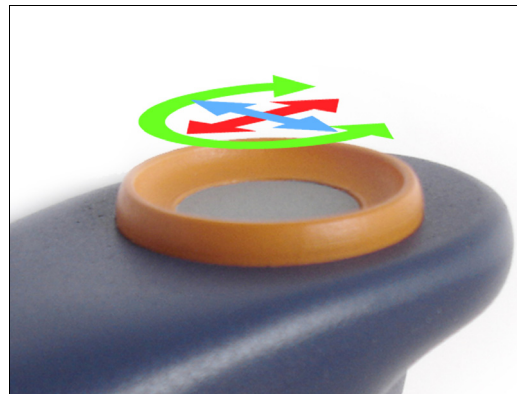


Figure 5: Isotonic touchpad as a 3-DOF rotation controller

Both the elastically suspended ring and the touchpad are integrated in the design of the device as a connected arrangement to be used with the thumb. We named this combination of sensors the "Groovepad".

3.3 Software implementation

To test the device, we implemented an interactive presentation of virtual objects and presentation slides in a three-dimensional building consisting of a number of different rooms. The exploration of this environment is implemented in the following way:

For travelling through the rooms, the pointing direction of the input device indicates the walking or flying direction. The rocker-lever specifies the velocity of the movement (Fig.6). Objects can be selected and moved along the image-plane with a cursor, that is controlled by a pointing gesture. The rocker-lever allows translation along the indicated direction through rate-control.

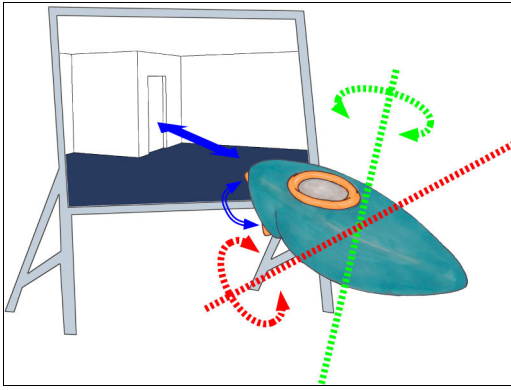


Figure 6: Travel interaction

For sensitive control of sliding movements parallel to the image-plane (2D) – without affecting the longitudinal axis – the elastically suspended ring on top of the device is used (Fig.7). It works similar to a joystick and offers an easy way to adjust object or viewpoint positions.

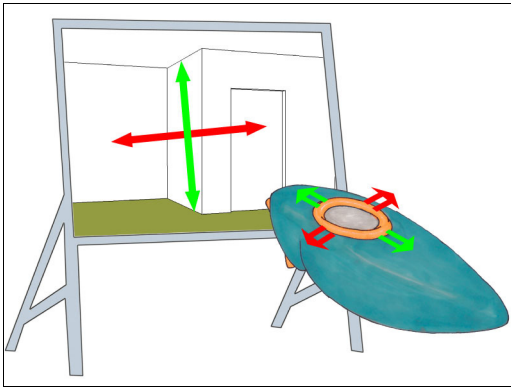


Figure 7: Sliding motion

For three-dimensional rotation the round touchpad is used. It allows the direct control of rotation angles for all axes, but prefers "head" rotation. Around the vertical axis, objects can be continuously rotated through a corresponding movement of the thumb. (Fig.8)

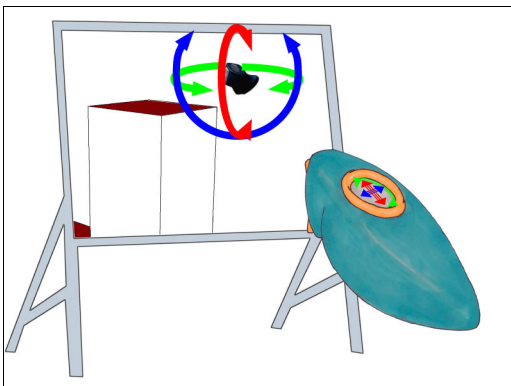


Figure 8: 3D rotation through 2D motion on a touchpad

4. CONCLUSIONS AND FUTURE WORK

We presented a novel 3D interaction device. Its design is based on a preceding task analysis to identify the necessary functionality. The "two - 4 - six" device was designed for the use with navigation centred applications like architecture reviews and games. Our design combines isotonic and elastic sensors as well as a gyroscopic tracker in a single device. The appropriate spatial arrangement and the functionality of the sensors were specifically chosen for the described interaction tasks.

A prototype of the device was used to navigate through a presentation of three-dimensional design objects. These can be selected and manipulated for closer examination. This type of presentation worked well and showed the benefits of virtual environments for the explanation of complex spatial data.

We are currently preparing a user study to verify the usability of the device. In this evaluation we will compare the presented interface concept of pointing and manipulating with other common 3D interaction techniques.

5. ACKNOWLEDGEMENTS

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