The Globefish: A 3D Motion Controller

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Abstract

The Globefish is a novel desktop input device for efficient three-dimensional object manipulation and viewpoint navigation. The device was developed for the 3D graphics applications such as computer aided design (CAD), digital content creation (DCC) and 3D games. The Globefish consists of an elastically suspended 3D trackball, which provides a natural mapping for position-controlled 3D rotations. 3D translations are rate-controlled through small displacements of the trackball against the elastic counterforces of the elastic suspension. The device is operated by the fingertips allowing for precise interaction with virtual objects.

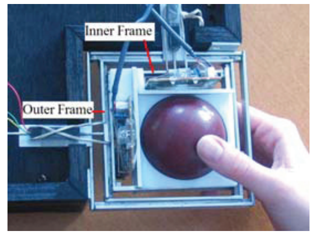

Figure 1: The first prototype

Figure 2: A later iteration

1 Introduction

Manipulating objects in 3D is a central task in most digital-contentcreation systems. We observed users performing this task while using an integrated 6-DOF input device, the commercially available Spacemouse^{TM}. They alternated between rotating and translating and rarely used both operations simultaneously. So, we decided to build an input device that uses separate sensors for these two interaction modes and allows rapid switching between them. This is the central idea of our Globefish, a custom 3-DOF trackball embedded in a spring-loaded frame (figure 1). The trackball sensor measures the rotation of the ball, which is manipulated by the fingertips, and transforms the sensor reading into a corresponding rotation of a virtual object. Tightening the grip on the trackball and pushing or pulling it in any direction controls the virtual objects translation along all spatial dimensions.

We conducted a series of user studies that revealed several distinguishing characteristics of the Globefish compared to the fully elastic SpaceMouse device [1, 3]. The directness of position-controlled rotations and also the tangible distinguishability of elastic translational input and isotonic rotations are the main contributing factors to the improved usability of the device in comparison to the SpaceMouse.

2 Ergonomics

Precise and comfortable interaction required that the trackball could be grabbed from two opposing sides. However, a priori it was not clear which sides this should be. In the first series of prototypes the trackball had to be clamped from the top and bottom between the user's fingers (figure 1). The design facilitated in particular the operation of vertical translations as well as rotations around both horizontal axes. Operating these devices was not very comfortable, since the hand's posture was neither very relaxed nor well supported.

We identified head rotation and linear motion in depth as the most important degrees of freedom for typical virtual reality applications [2]. Thus our device design should rather favor the operation of these axes. Based on this observation, we designed another prototype, which allowed users to grab the trackball from the front and the back (cf. figure 2). In addition, this design supported a comfortable hand posture similar to writing with a pen.

Public presentations of the new device design exposed another issue: it remained unclear to the users how the trackball should be grasped if there was no explanation provided. Since the trackball was freely accessible from the top, users recognized the device as a regular 2D trackball and tried to rotate it with single finger. Thus we slightly changed the design such that the trackball is now covered at its top and laid open towards the operating hand. This small adaptation (cf. figure 3) did not only solve the described problem, but it also provided a larger operating space for the fingers for inducing rotations around the vertical (head) as well as the lateral (pitch) axis.

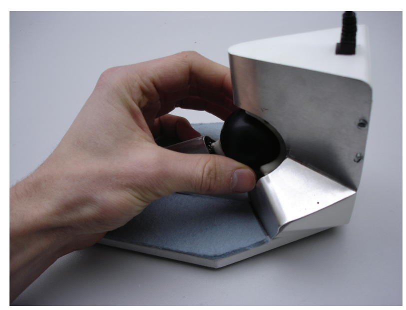

Figure 3: The most recent prototype of the Globefish 3D input device.

3 Technical Details

The Globefish device does not only enable rotational but also translational input that can be induced by small deflections against the counterforce of the springs. The trackball is mounted in a four point bearing arranged as an equilateral tetrahedron. This design provides consistent friction for all rotation axes. To measure 3D rotational input we could directly use existing 2D mouse sensors, which are mounted inside the trackball's enclosure to track the moving surface of the trackball. In theory the 3D rotation can be computed from at least two of such cameras that could be arbitrarily placed

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around the trackball. In practice however, we found that the computed rotation is not always accurate because mouse sensors report only relative data. Due to the high resolution of the mouse sensors the error is very small and only noticeable when trying to rotate exactly about one of the axes of the coordinate system axes. This issue could be perfectly resolved by mounting the cameras directly on the principal axes (figure 4).

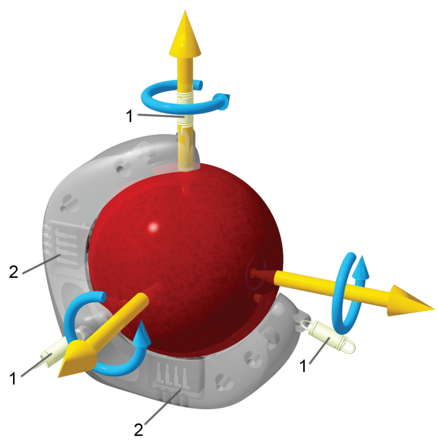

Figure 4: The technical implementation of the Globefish device: (1) Inductive spring sensors for elastic translational input. (2) Optical motion sensors for isotonic rotational input.

The selection of the best sensor electronics for the translational input was not as straightforward. We experimented a lot with mechanical and optical sensing methods. Finally we came up with the solution to suspend the trackball with prestressed springs arranged in the same tetrahedron structure as the bearing points holding the trackball. The extension of the springs is directly derived from measuring the changes of the inductance of the conductive springs. The trackball's deflection is computed by trilateration.

4 Design Variations

We are currently working on further variations of the Globefish idea. The Globewing is a two-handed input device consisting of two Globefish sensors, each providing six degrees of freedom (figure 5). While the dominant hand manipulates virtual objects, the camera viewpoint may be simultaneously controlled by the non-dominant hand.

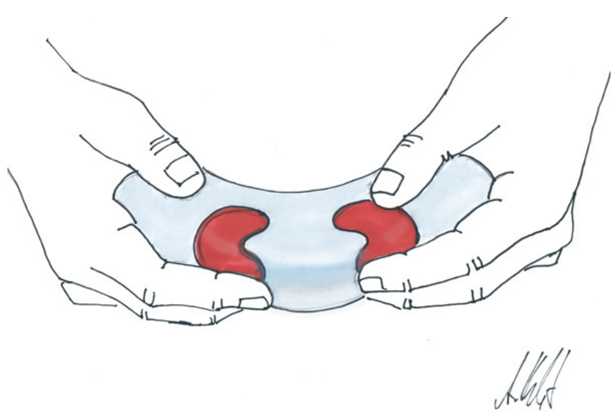

Figure 5: The Globewing is a handheld input device, which allows the manipulation of six degrees of freedom by each hand.

The Spheron supports collaborative group interaction taking place in front of large display walls (figure 6. It is designed to facilitate 3D interaction tasks for presentations and for design reviews in mechanical engineering and architecture.

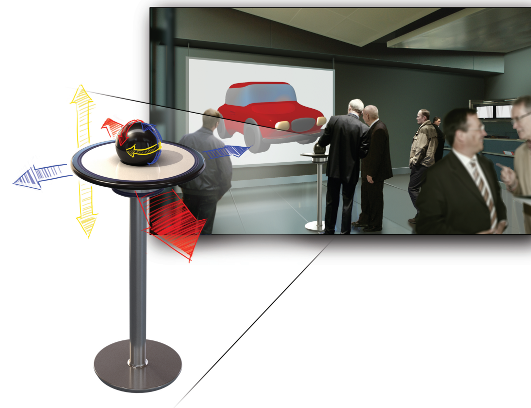

Figure 6: The Spheron is an input device for collaborative design reviews in virtual reality.

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References

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