Vectorix: A Low-Tech Mechanical Tracking System

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Abstract

This paper introduces a simple mechanical three degree of freedom tracking system, which is based on the idea of a spherical coordinate system. Our system measures two angular coordinates and the length of a string. This information is used to compute three-dimensional Cartesian coordinates, which are typically used in virtual environment applications.

We integrated this idea of a three-dimensional position tracker into two different setups. Our first setup is a free standing device with a tracked handle. The handle is attached to a separate tracking unit at each end, which provides us with a total of five degrees of freedom. Our second version uses a single tracking unit attached to the shoulder of a user. The string is attached to the wrist of the interacting hand. This setup provides body-referenced three-degrees of freedom tracking, which could be used for HMD-based systems.

1. Overview

Tracking is the basic technology used in most virtual and augmented reality systems. Commercially available tracking systems are still quite expensive. For some situations much simpler tracking technology might be sufficient.

We present Vectorix, a low-tech and low cost mechanical tracking system. The basic idea of the system is shown in Figure 1. Two brackets rotate around orthogonal axes in the ground plane. The angle of each bracket is measured by a simple rotary potentiometer. A string runs through a hole in the middle of the ground plane and through the connection of the two brackets. The string is attached to the tracked object and pulled tight by a weight behind the ground plane. The string adjusts the two brackets such that they encode the direction of the string. The direction of the string is simply computed as the intersection of the two planes defined by the brackets. The length of the string defines the third coordinate. This approach is equivalent to the use of spherical coordinates and provides three degrees of freedom.

Figure 1. The Vectorix unit: 1 - string, 2 – metal brackets, 3 - rotary potentiometer

We integrated our tracking concept into two setups. The free standing setup employs two Vectorix units to track the position and two degree of freedom orientation of a handle (Figure 2). The end of the strings of the two tracking units are attached to the left and right side of the handle. The rotation of the handle around its main axis is currently not tracked. A counter weight keeps the strings under tensions and allows the movement of the handle with low forces. The length of the string is measured by the orientation of the large deflection roller on the left and right side of the setup. The interaction space of the handle is limited to a radius of around 0.2 meters around the rest position.

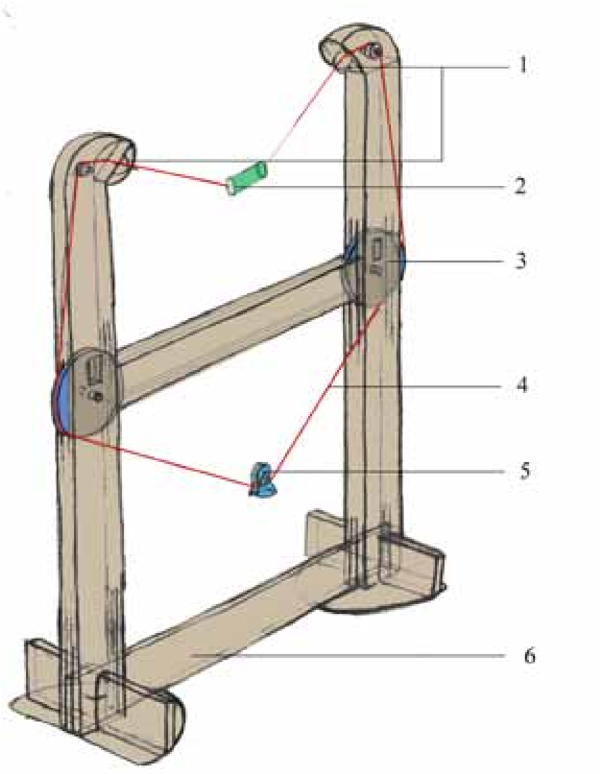

Figure 2. The free standing setup: 1 – Vectorix unit, 2 – handle, 3 - deflection roller, 4 - string, 5 – counter weight, 6 - frame

Our second setup uses a variation on the Vectorix idea to track the hand position relative to the user's body (Figure 3). The Vectorix unit is attached to the user's shoulder, which provides the reference coordinate system. The end of the string is connected to a spring loaded string roller mounted at the user's wrist.

Figure 3. The body-referenced setup.

For the body referenced tracking system we built a hand attached input device, which we named Mosca (Figure 4). The idea behind this input device is a light weight construction, which supports selection and basic manipulation tasks.

Figure 4. The Mosca device. Pointer and middle finger grab the front part of the device and the thumb manipulates a mini-joystick and a mouse wheel.

2. Technical Details

We use a USB analog-digital converter to measure the potentiometer values for the angular orientation of the brackets. The actual orientation of the deflection roller was originally measured through an optical approach. We glued a grey ramp onto the deflection roller. The grey ramp is locally illuminated with a light emitting diode (LED). The reflection of the grey ramp is measured using a photo sensor and corresponds to the current orientation of the roller. This approach turned out to be hard to calibrate precisely and we are now using a potentiometer.

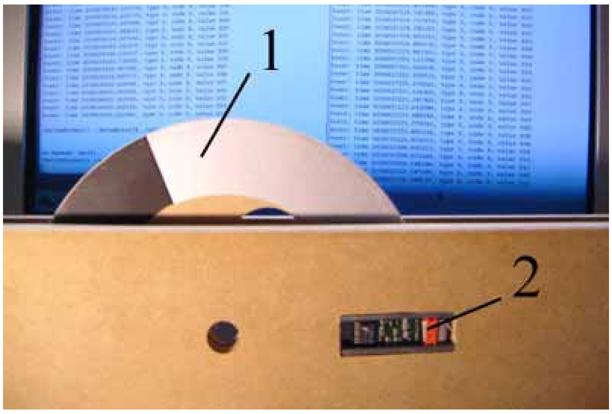

Figure 5. The deflection roller, 1 – grey ramp, 2 – analog-digital converter with LED and photo sensor.

The body referenced setup uses a different approach to track the angular coordinates (Figure 6). Two rotary potentiometers are mounted on top of each other. This configuration works well for only a small angular range around the main direction.

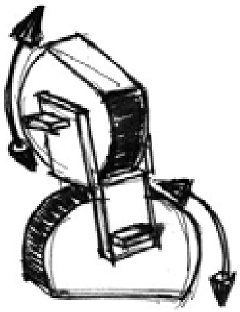

Figure 6. Two orthogonal potentiometers for measuring the angular coordinates.

The length of the string for the body referenced version is measured with a ten turn potentiometer mounted on the string roller shown in Figure 3 in orange.

3. Experiences and Disussion

The devices have been integrated into the Avango virtual environment framework [1]. For the free standing setup we built a small application prototype in Avango. The free standing tracking system controls the position and orientation of a virtual hand in a three-dimensional room. There is also a virtual bee flying around in the room, which the hand needs to catch. The bee is controlled by a second user and the Mosca input device.

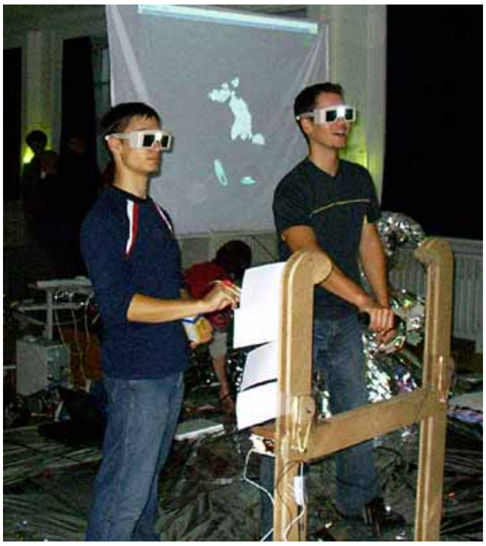

Figure 7. The free-standing setup in use. The left person is using the Mosca input device.

Our experiences with the free standing Vectorix system are overall positive. We showed the system and the Mosca during an Open House event to a few hundred people. Most people had no problems using the device and following the virtual bee. This type of interaction does not need to be very precise due to the direct visual feedback.

Some limitations are:

- One cannot just release the handle in an arbitrary position. The handle starts to swing and returns to the central rest position.
- Limited working range
- The string and the two metal brackets for the angular measurements do not move completely smooth for all situations.

The body-referenced setup has not yet been integrated into a test application and needs further refinement of the angular measurement part.

4. Conclusions and Future Work

Our experiment shows that it is possible to build a low-tech and low cost tracking system that works well with game-type application scenarios. We are convinced that the implementation of the Vectorix concept with higher quality components and some more engineering would result in a precise and low latency tracking system. In particular rotary encoders and conductive plastic potentiometers would reduce the required string pulling force.

Many other application scenarios for this type of tracking system are imaginable. A wall-mounted vectorix unit could be used to provide absolute position information in a room or to roughly digitize a real model. The most interesting idea is the use of a vectorix unit in a two-handed input device. The device consists of two parts: a base hold by the non-dominant hand and a detachable part manipulated by the dominant hand. The base contains a Vectorix unit, which is connected to the detachable part. This setup allows interaction techniques, which use the non-dominant hand as a reference system. The dominant hand acts within this reference frame. This division of roles between the non-dominant and dominant hand are very much in line with Guiard's observations [2].

References

1. *Tramberend, H. Avocado: A Distributed Virtual Reality Framework. Proceedings of VR'99 Conference, Houston, Texas, 14-21, March 1999.*
2. *Yves Guiard. Symmetric division of labor in human skilled bimanual action: the kinematic chain as a model. The Journal of Motor Behaviour, 19(4):486–517, 1987.*