High-Precision Hand Interface

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Abstract. Virtual reality techniques have been introduced to propose the intuitive interface in virtual entertainment environments. We introduce the intuitive and natural interaction interface supporting the high-precision hand operations. In this paper, we describe the novel sensing mechanism of finger tracking with fast refresh rate and high resolution.

1 Introduction

One of the recent key issues for virtual reality technologies is the natural interaction between the humans and a virtual environment. An interface based on hand input to virtual environments would be the most natural method to interact with the world [6].

Since Zimmerman, et. al. (1987) introduced optical fiber sensor-based glove devices, Immersion, Inc. markets the CyberGlove, an instrumented glove primarily designed for manipulation of 3D object in commercial CAD [1,5]. However, these glove devices have a weak point to utilize the hand interface for entertainment environment (temperature/size of user's hand/time consuming calibration) [2].

In this paper, therefore, we suggest the high-precision hand interface with higher resolution, faster refresh rate and robustness compared to the existing sensors such as resistive strip or optical fiber.

2 High-Precision Hand Interface

As shown in Figure 1, we present high-precision hand interface which consists of comfortable and precise finger tracking hardware device, hand API, realistic hand model and calibration tool for precise operation.

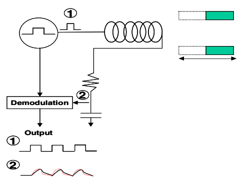
Fig. 1. Glove-type hand interface

R. Harper, M. Rauterberg, M. Combetto (Eds.): ICEC 2006, LNCS 4161, pp. 378 – 381, 2006.

2.1 Robust Sensing Mechanism for Finger Tracking

Our glove-type hand interface mounts LEVEX's LVDT(Linear Variable Differential Transducer)-type linear position sensors for measuring the precise micro displacement[7].

As shown in Figure 2, this sensor consists of a primary coil and two secondary coils wound on a coil form. A ferromagnetic core links the electromagnetic field of the primary coil to the secondary coils. Differencing the output of these coils will result in a voltage proportional to the relative movement of the core versus the coils. Compared to the other techniques, LVDT-type linear position sensor with high accuracy operates linearly with an extremely low temperature coefficient. Furthermore, LVDT-type linear position sensor has robust sensing features for finger tracking regardless of size of user's hand. This advantage gives users less calibration time.



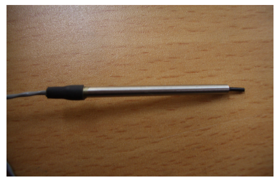


Fig. 2. Concept of LVDT-type linear position sensor & actual sensor

2.2 Direct Measurement for Finger Tracking

As shown in Figure 3, current joint angle of the each finger can be calculated from the measured voltage of sensor because the movement displacement of finger joint(length of arc) is proportional to the central angle(θ= r l).

Therefore, user's current joint angle can be solved to the following as;

$$At_{(i)} = \frac{Vt_{(i)} - V\min_{(i)}}{V\max_{(i)} - V\min_{(i)}} \times A\max_{(i)} \quad (1)$$

where, $At_{(i)}$ is user's current i^{th} joint angle and $V\max_{(i)}$ is the maximum voltage value of the i^{th} joint maximally spreaded out. The $V\min_{(i)}$ is the minimum voltage value of the i^{th} joint maximally clenched and $A\max_{(i)}$ is the maximum range of i^{th} joint.

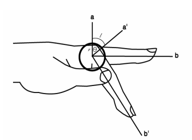


Fig. 3. Direct measurement of finger joint angle

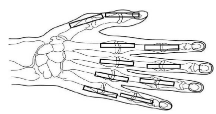


Fig. 4. Layout of sensor arrangement

As shown in Figure 4, our glove mounts the only 2 sensors for each finger on the assumption that the angle of third joint can be predicted from the angle of second joint because the third joint movement of each finger depends on the 2^{nd} joint movement of finger from an anatomical point of view.

2.3 Hand Interface API

Hand interface API performs the device initialization, connection, I/O data streaming and supports the easy integration environment to any virtual reality application.

We have migrated OpenSG scenegraph to our Hand interface API. OpenSG is an open source real-time rendering system based on a scenegraph metaphor on top of OpenGL [4]. Hand high-level API performs the collision detection from the scene-graph traversal for various grasp geometrices. We predefine a hierarchical representation of the models using tight fitting oriented bounding box trees. Through the scene-graph traversal, hand high-level API receives current transformation information about pre-defined objects, and then computes collision status. Hand high-level API support AABB, OBB and polygonal-level API for real-time collision detection.

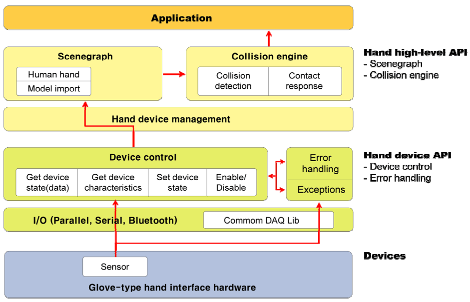


Fig. 5. Architecture of hand interface API

Fig. 6. Virtual hand model

As shown in Figure 6, to give users natural visual satisfaction, we have implemented a natural deformation of joint movement by using deformable skin mesh control technique. Thus, it is possible to precisely adjust the hand interface hardware comparing the virtual hand model [3].

2.4 Calibration Tool

Calibration tool has an important role to store the measured minimum /maximum voltage values, maximum angle range of each finger. As shown in Figure 7, the calibration process is simply done by the two hand gestures.

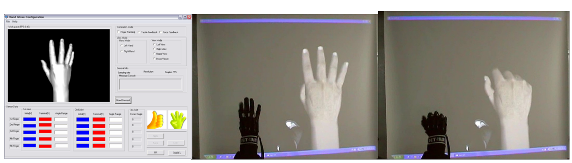


Fig. 7. Calibration tool and two hand motion for calibration process

3 Experimental Result and Application

We made an experiment on the linearity of LVDT-type linear position sensor. As shown in Finger 8, this sensor is available in strokes from 0.01 to 15mm. Maximum non-linearity is specified as ±0.4% of full scale. This sensor shows the 4kHz update rate, 12bit high resolution and good repeatability.

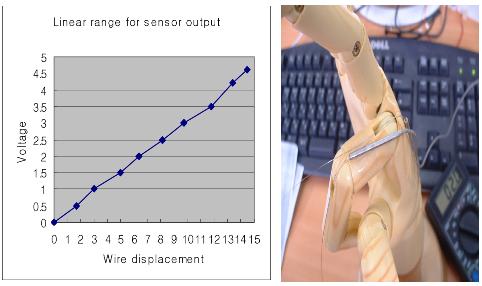


Fig. 8. Linearity of sensor output

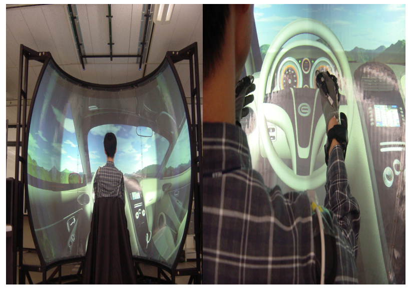


Fig. 9. Interaction using hand interface

As shown in Figure 9, we have developed a car interior review system which is based on a curved display of hemi-spherical. Usability test are operated in this platform such as evaluation of interior of car or information appliance by developed natural and intuitive hand interface.

4 Conclusion and Future Work

We introduce the intuitive and natural interaction interface for virtual reality applications. Currently, we are trying to develop the haptic feedback actuators to give users realistic force/tactile sensation and the haptic API including haptic modeling, fast haptic cycle.

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