A 3-D Computer Game Controller: Design and Applications

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1. Introduction

During the past few decades from the invention of first gaming systems, there have been only a few designs for 3-D game controllers, most of which were released in limited numbers due to their high cost. These controllers were as a result targeted towards virtual reality applications and have less been used for home gaming applications. Ultrasonic ranging [Logitech 1992] and image processing techniques [Marks 2000] are among the methods used to track the position of the handheld compartment (HC) of the controller. Both of these methods impose some requirements on the environment in which they are utilized in, to have the desired performance. Highly reflective surfaces or materials in the vicinity of the transceivers cause unwanted echoes in the received signal which degrades the performance of ultrasonic ranging methods. Image processing techniques require high processing power and some sort of distinction, usually in color, between the background and the HC. Additionally, both of these methods fall short in tracking fast motions of the controller, which further limits their application.

In this work, a novel design for a 3-D computer game controller using Micro-Electro-Mechanical-Systems (MEMS) sensors is presented. The proposed design is virtually independent of the environment in which it is used and requires small processing power.

2. Exposition

To determine the position and orientation of the HC, knowledge of six geometrical parameters is required namely, the three ordinates of an arbitrary point P on the HC with respect to a fixed reference coordinate system (CS) and the three inclination angles between a CS attached to that point and the reference CS. The above parameters can be directly defined as a function of acceleration and angular velocity and the initial conditions as

$$\ddot{x}(t) = \frac{d^2 x(t)}{dt^2} \tag{1}$$

$$\dot{R}(t) = \frac{dR(t)}{dt} = Skew(\omega(t))R(t) \tag{2}$$

where $x(t)$ represents the position of P, $\omega(t)$ is the angular velocity vector, $R(t)$ is the rotation matrix defining the orientation at each instant of time t. $Skew(u)$ for any vector u is the skew symmetric matrix such that $Skew(u)v = u \times v$, for any vector v, where $\times$ denotes vector cross product [Eberly 2004].

Invoking the above equations and knowing the instantaneous acceleration and angular velocity of a moving object, one can determine the position and inclination of the object at any instant in time.

To measure the real-time acceleration and angular velocity, MEMS accelerometers and gyroscopes are mounted on the HC. A microcontroller reads samples of the measurements from these miniature devices in time, and using numerical methods solves the differential equations (1) and (2) to determine the instantaneous position and inclination of the HC. By proper choice of the sensors, the sensitivity, resolution and range of detectable motions can be tailored for different practical applications.

The preliminary results obtained from a constructed prototype show that with a small processing power (i.e. that of a 16-bit microcontroller), for solving equations (1) and (2), acceptable performance can be achieved. This result agrees with those of 2-D positioning system reported by Lee [2001].

The proposed system can be used in a variety of applications including, computer gaming, virtual reality and sports training. Using a wireless transmitter, on the HC, its position and inclination can be calculated on the device and transmitted to the host gaming system, eliminating need for wires to connecting the HC and the host gaming system.

3. Conclusion

A 3-D computer game controller design using MEMS sensors is presented. The proposed design can be used as a 3-D controller for virtual reality applications and home computer gaming. The system can be used to track relatively fast motions and as a result can be also used for sport training purposes such as fencing. This design is virtually independent of the environment in which it is performing. The only factor that affects the performance of the system is sudden changes in the temperature of the environment while other factors can be mostly compensated for in software. The design requires small processing power and can be implemented on a microcontroller. Using RF transmitters, the device can also work untethered.

References

LOGITECH, 1992. 3D mouse and head tracker. Technical reference manual, available online at www.vrdepot.com/manual-tracker.pdf

RICHARD MARKS, 2000. Medieval Chamber. *Emerging Technologies, etech 58, SIGGRAPH.*

SEUNGBAE LEE, GI-JOON NAM, JUNSEOK CHAE, HANSEUP KIM, and ALAN J. DRAKE, 2001. Two-dimensional position detection system with MEMS accelerometers for mouse applications. In *The Proceedings of the 38th Design Automation Conference (DAC 2001)*, Las Vegas, NV.

DAVID H. EBERLY, 2004. Game Physics, *Elsevier.*