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ESTIMATION OF ORIENTATION WITH GYROSCOPES AND ACCELEROMETERS

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Abstract* – *3D orientation obtained by integrating the rate gyroscope signals can be improved by fusion with inclination information obtaine.l from 3D accelerometer signals. This is relevant for ambulatory human movement analysis.

INTRODUCTION

Many systems for recording human movement need some reference from beacons near the subject, such as video cameras. Our goal is to measure human kinematics with sensors that are placed on the segments of interest. This way, experiments in which human movement is recorded are not restricted to a lab.

Our inertial sensor-unit consists of a little box with three miniature gyroscopes (Murata ENC05E) and three linear accelerometers (AD xl05) that measure 3D angular velocity and linear acceleration, respectively. This abstract describes a way to fuse both sensors (gyroscopes and accelerometers) to obtain an estimate of the orientation that is both accurate and limited in integration drift.

METHODS

Both the gyroscope and accelerometer signals contain information about the orientation of the sensor. The sensor orientation can be obtained by integration of the angular velocity signals obtained from the gyroscopes [1]. This operation introduces integration drift in the estimated orientation.

Accelerometers do not only measure the acceleration of the sensor, but also the gravitational vector. This gravitational component not only has a bigger magnitude for many human movements but also always points downwards. This knowledge can be used to make an estimation of the tilt. The tilt is defined as the angle between the sensor axes and the vertical. This tilt estimation is not very precise but does not suffer from integration drift.

The orientation that is calculated with gyroscopes is split into a tilt part and an angle that represents a rotation around the vertical (fig. 1). This tilt from the gyroscopes is fused with the tilt from the accelerometers with a Kalman filter [2].

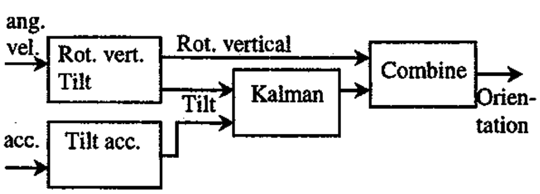

Fig. 1: *Block diagram of orientation estimation. Tilt is measured from gyroscopes and accelerometers is fed into a Kalman filter to obtain an improved estimate of tilt.*

The algorithm was tested by taking the sensor and moving it around by hand. By putting it in a known position once every 30 seconds, we were able to determine the error of the calculated orientation.

RESULTS

Figure 2 shows an example of the error of the calculated orientation in time. The error is defined by the amount that the calculated orientation has to rotate in order to coincide with the real orientation. As a reference, the orientation error is also determined when only integrating gyroscope signals [1].

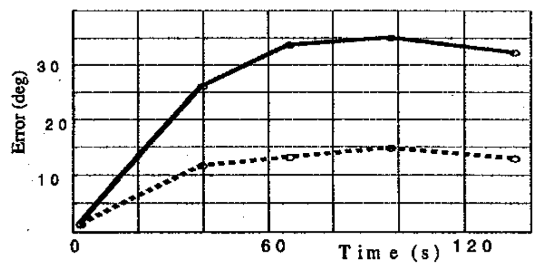

Fig. 2: *Example of calculated orientation error, by integration of gyroscope signals according to Bortz [1] (solid) and by Kalman filtering of gyroscope/accelerometer signals (dashed).(Example trial)*

CONCLUSIONS

As shown in figure 2, the combination of gyroscopes with accelerometers can give a considerable improvement of the estimated orientation. Since accelerometers do not give information about rotation around the vertical, there will still exist integration drift around the vertical axis. This could be diminished by making an error model of the sensors that can be used to re-estimate sensor parameters.

ACKNOWLEDGEMENT

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REFERENCES

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[2] Brown, R.G., Hwang, P.Y.C., *Introduction to Random Signals and Applied Kalman Filtering*, 3rd ed. John Wiley & Sons, ISBN 0-471-12839-2