

AN INSTRUMENTED INSOLE FOR MEASUREMENT OF FOOT MOTION

Chris Kirtley

Dept. of Biomedical Engineering, The Catholic University of America, Washington DC, USA

INTRODUCTION

The methods currently available for the measurement of foot motion have several inherent disadvantages. Video-based systems using skin-attached markers suffer from artifact due to motion at the skin-bone interface (Reinschmidt et al, 1997). It is also very difficult to track individual bones, so the foot is usually modeled as a single segment. Moreover, the amount of data that can be collected is limited to a few steps at a time and it is difficult to accommodate footwear.

Recently, miniature sensors have become available as a result of Micro-Electro-Mechanical Systems (MEMS) techniques (Kirtley, 2002). These sensors are capable of accurate measurement of angular velocity and linear acceleration, and operate on very low power. This study investigated the use of such sensors, incorporated into an instrumented insole (Figure 1) for ambulatory measurement of foot motion.

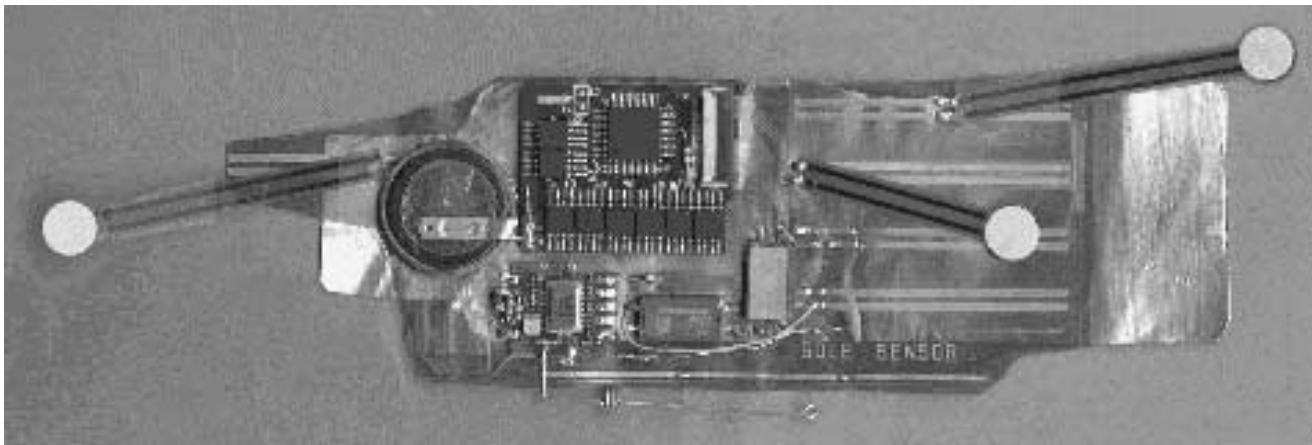


Figure 1: Instrumented insole with gyro and accelerometers, microcontroller and EEPROM memory (Kirtley C, 2001).

METHODS

The combination of a gyro sensor (ENC-03J, Murata, Japan) and a bi-axial accelerometers (ADXL202, Analog Devices, MA) were incorporated into an instrumented insole (Kirtley, 2002). The gyro output, ω , following integration, tracked the angle of the foot, ϕ . Auto-nulling of the derived angle (which was prone to drift) was ensured by resetting the integral to the angle of the foot as measured by the accelerometer (Mayagoitia et al, 2002). This could be done whenever the foot was stationary for a period of time, since at this time only the gravity vector was acting on the accelerometer, which thus functioned as used as a tilt sensor (Figure 2).

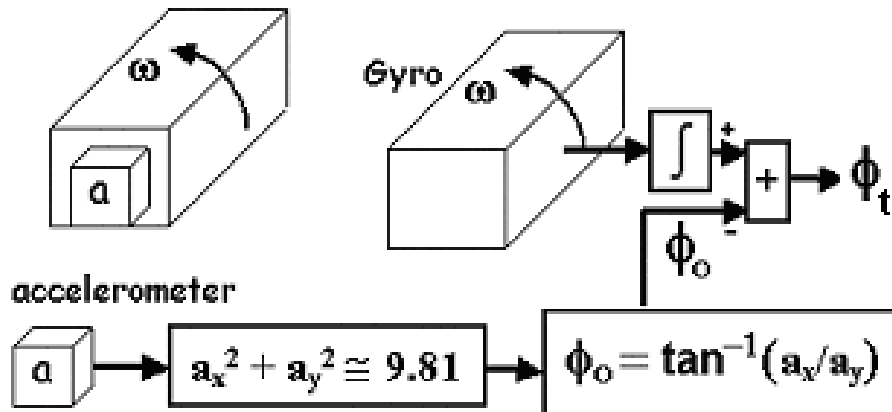


Figure 2: Algorithm used for deriving foot angle from gyro and accelerometer signals.

One gyro/accelerometer combination was orientated along the longitudinal axis of the foot, in order to measure the angle in the sagittal plane, while a second set was orientated such that it recorded in the frontal plane.

The optimal threshold band ($\pm g$) during which the foot was assumed stationary for auto-nulling purposes, was determined empirically to be 5%. Thus, the integral was reset when the resultant acceleration recorded by the accelerometer was within $\pm 5\%$ of 9.81 ms^{-2} .

RESULTS AND DISCUSSION

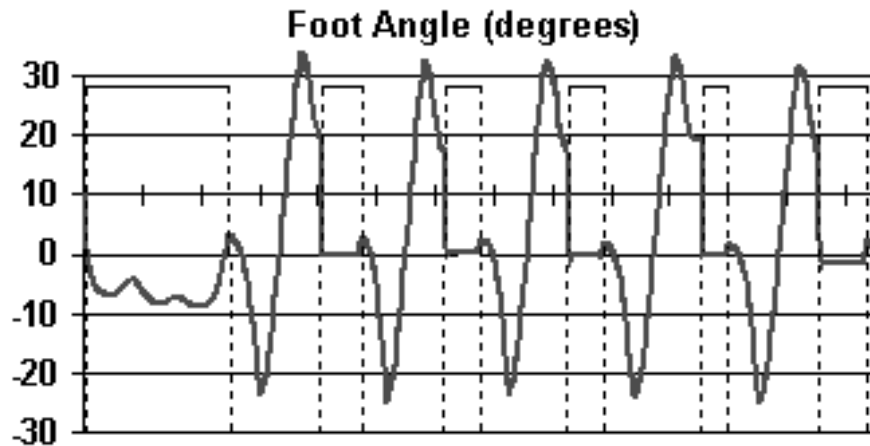


Figure 3: Foot angle as recorded by gyro/accelerometer combination. The dashed line indicates stationary periods when the integral was auto-nulled by the tilt signal.

SUMMARY

This technique offers potential for inshoe ambulatory monitoring of foot angle.

REFERENCES

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