Estimation of relative body segment orientations during movement using accelerometry

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Introduction

Quantitative assessment of human body movements includes the analysis of joint orientations. We propose a new method to estimate relative orientation between body segments using a single 3D accelerometer per segment under the following conditions:

(1) The total acceleration on both segments is the same. They are only measured in different coordinate frames.

(2) The direction of the total acceleration changes with time.

(3) The relative orientation changes relatively slowly with respect to the total acceleration.

These conditions may be satisfied in certain situations, for example on the segments of the fingers of a hand during functional movements.

Methods

We tested this method using an experimental setup with accelerometers on a kinematic body chain with fixed relative orientations. The distance between the axis of rotation and accelerometers was 35 mm and 75 mm respectively. Two movement conditions were performed:

(1) Cyclic translational movement over 45 centimeters at 0.8Hz, see figure 1.

(2) Cyclic rotational movement over 180 degrees at 0.8Hz.

Results:

Accurate relative orientations were obtained when performing horizontal translational movements (Figure 1), but as expected, errors occurred at higher angular velocities during pure rotations.

Movement	Distance	Maximum Error
Translation	4 cm.	4 deg.
Rotation	180 deg.	60 deg.

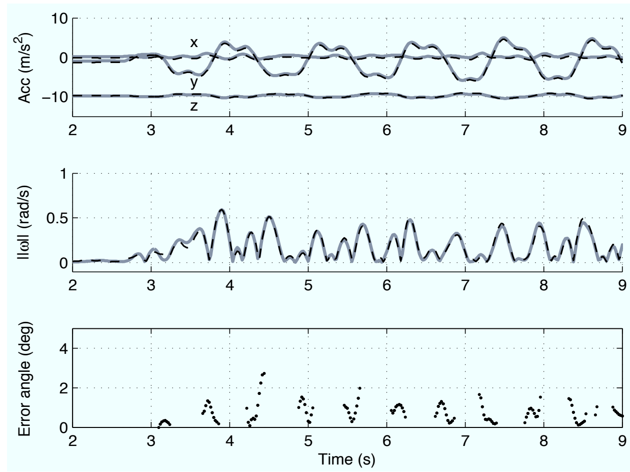

Figure 1. Cyclic translational movement (cond. 1). The first two rows show the output of both inertial sensors (solid grey and dashed black). The plot on the third row shows the angle between the estimated and real orientation between both sensor frames if an estimate could be made.

Conclusion / Discussion

The proposed method may be useful to estimate relative orientations between body segments using only a single accelerometer per segment. Especially when multiple body segments experience the same translational accelerations, for example the individual finger segments during functional reach movements of the hand.

The proposed concepts will be implemented in a 'PowerGlove', which aims for the estimation of kinematics and kinetics of the human hand during interactions with the environment.

Acknolewdgement

This research is supported by the Dutch Technology Foundation STW, which is part of the Netherlands Organization for Scientific Research (NWO) and partly funded by the Ministry of Economic Affairs, Agriculture and Innovation.