Research Consortium in Speckled Computing

Distributed Posture Tracking

Alex Young

University of Edinburgh

a.d.young-2@sms.ed.ac.uk

Overview

- Goal
- Existing Systems
- Theory of Operation
- Available Sensors
- Prototype System
- Video Demonstrations

Goal

- Many applications require knowledge of body posture
  - Animation
  - Gesture recognition
- Traditional posture tracking often impedes subject
- Goal – ***To track body posture with minimal inconvenience to subject***

Existing Systems

- Vision systems
  - Use multiple cameras to produce 3 dimensional model
    - Subject must remain in vision of cameras
  - Occlusions a major problem
    - Other people, objects, etc.
  - Requires complex computations
    - Large amounts of data
    - Edge detection, motion tracking...

Existing Systems (2)

- Joint angle sensors
  - – Physically covers the subject’s joints
    - Restricts movement
  - – May provide the most accurate track

http://www.measurand.com/products/ShapeWrap.html

Existing Systems (3)

- Inertial tracking
  - Uses acceleration and rotational rate data to estimate position
  - Requires a known start position
  - Errors in sensor input produce cumulative output errors
    - Even small errors in input will produce a large error over time

Requirements

- Sourceless sensing
  - Does not require externally generated input source
- Wireless
  - Less intrusion to the subject
- Low computation
  - Reduces power consumption
  - Allows reduced device size / longer battery life

Theory of Operation

Two (or more) non-colinear, non-zero vectors known in two reference frames can yield the rotation matrix that takes one frame to the other

- A suitable choice for such vectors are gravity and the Earth's magnetic field
  – Rotation matrix is found using an orthogonalisation process to produce 3 basis vectors from the 2 input vectors

Reference Frames

- Earth-fixed reference frame
  - X-axis points to Magnetic North resolved into the horizontal plane
  - Z-axis points in the direction of gravity
  - Y-axis points east to complete right-handed co-ordinate frame
- Body reference frame
  - X-axis points in the direction of the bodies major axis
  - Y- and Z-axes arbitrarily defined to complete right-handed co-ordinate frame

Available Sensors – Accelerometer

- MEMS accelerometers measure the force applied to a small test mass suspended on micro-machined beams
  - Output capacitance varies with acceleration and can be converted to a voltage output
- 3 orthogonal accelerometers give the components of the device's acceleration
  - When averaged over time these produce a vector pointing in the opposite direction of the local gravity vector

Available Sensors - Magnetometer

- 4 Magneto-Resistive (MR) elements arranged as a Wheatstone bridge give a differential output proportional to magnetic field strength along the sensitive axis
- 3 bridges mounted orthogonally give the direction of the Earth's magnetic field vector
  - The horizontal component of the Earth's magnetic field vector points towards magnetic north
  - Field will be distorted by ferrous objects

Available Sensors – Rotational Rate

- Gyroscopes produce a voltage output proportional to angular velocity
  - Integration over time yields rotation from known start point
- Suffer from offset drift
  - Device appears to constantly rotate slowly
  - Integration causes errors to accumulate
  - Offset temperature co-efficient makes offset nulling difficult in practice

From Orientation to Position

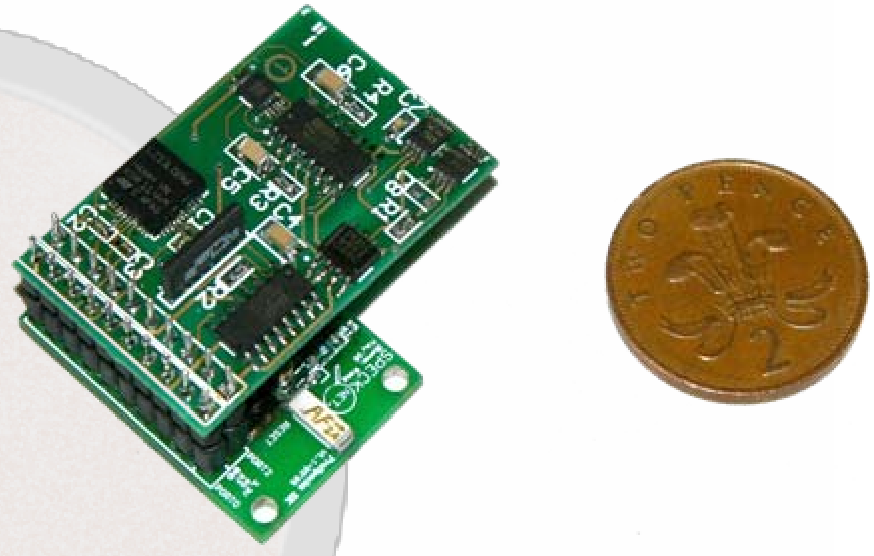
- Position information can be found by simple vector addition
  - The body being tracked is split into rigid segments
  - Each segment is equipped with a speck
    - The length and orientation of each segment is known
  - The segments form a tree
    - Given the location of one point all others can be found
    - For posture tracking of one person this start point can be simply set to a constant

Position Algorithm

- Position calculated recursively from tree root
    1)Each segment receives its start position
    2)The length vector is rotated from the body frame into the Earth-fixed frame
    3)The rotated length vector is added to the start point to find the end point
    4)The end point is sent to the children segments as their start point
- Can easily be distributed between nodes

Orientation Sensor Board

- A 3D compass based on the ProSpeckZ-IIK
  - Honeywell HMC-105x series MR magnetometers
  - STMicro LIS3L02AQ tri-axial MEMS accelerometer

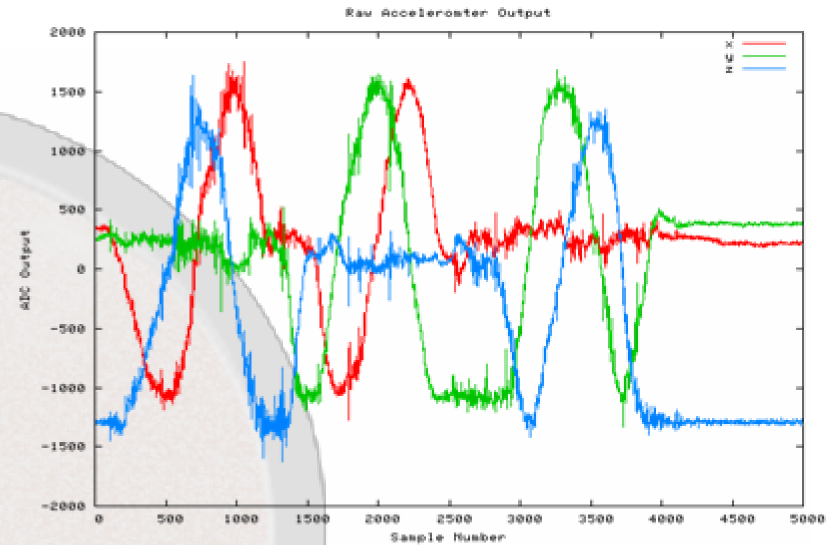


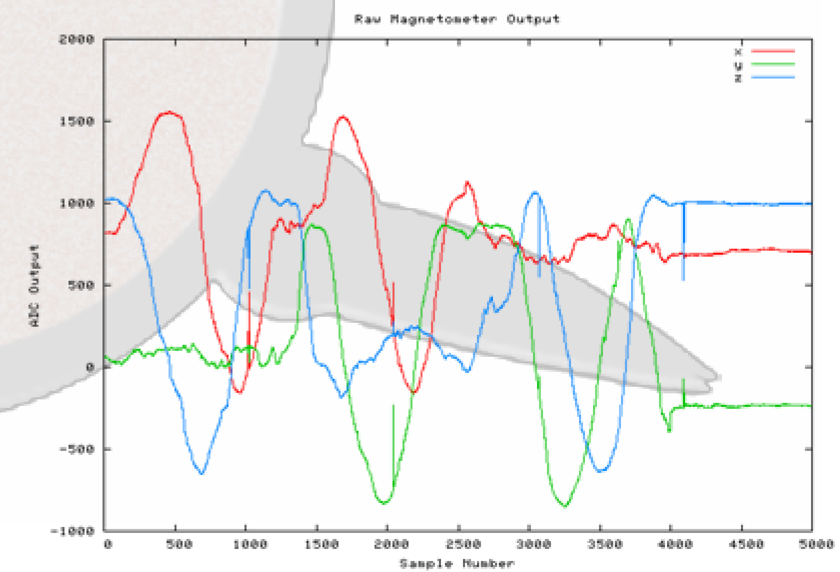
HMC1053 tri-axial magnetometer – 16Pin-LCC ~7x7mm

LIS3L02AQ tri-axial accelerometer – 44Pin-QFN ~ 7x7mm

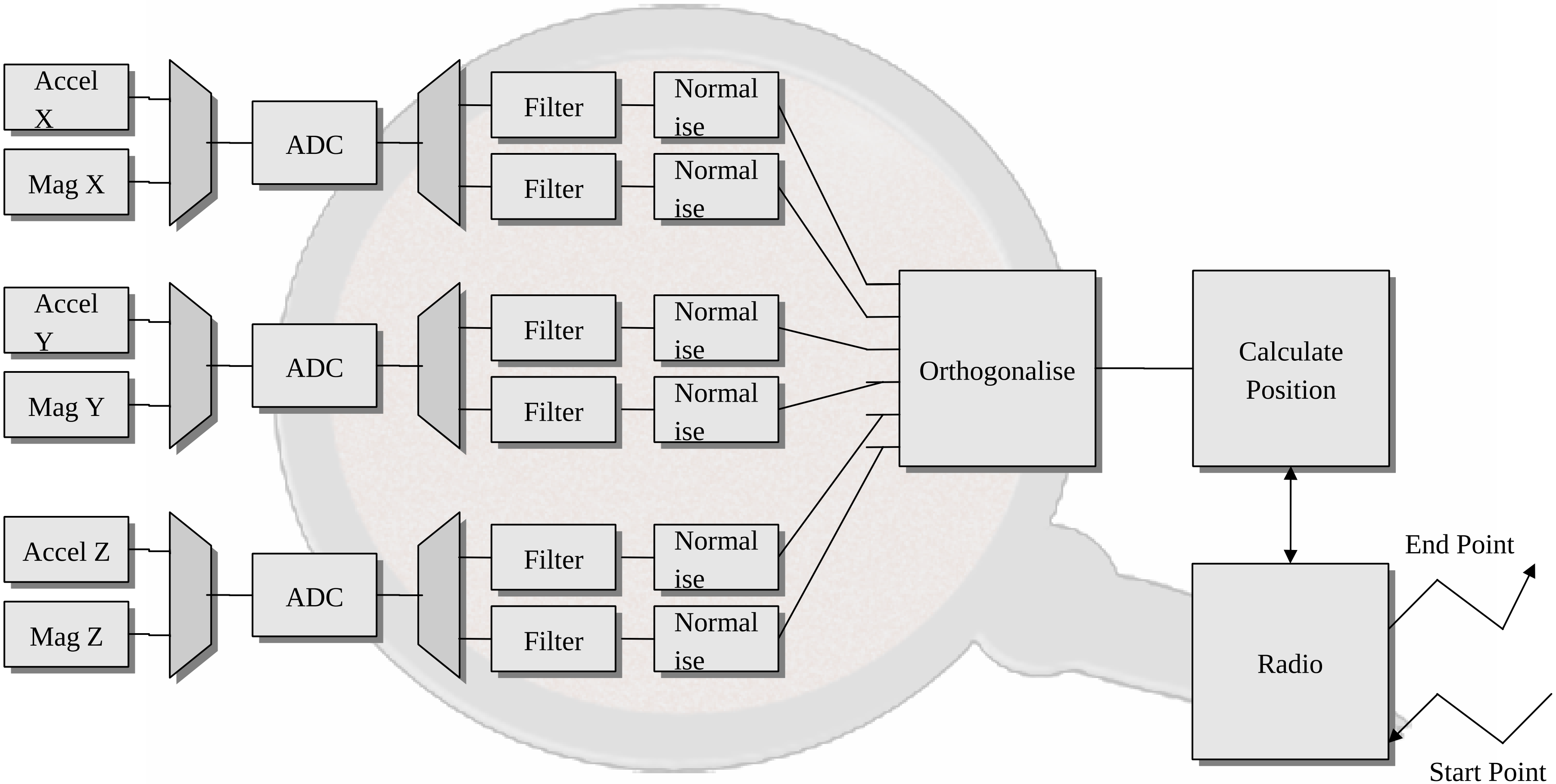
Raw Orientation Sensor Output

- Raw sensor output is noisy and can show significant offsets
- Requires filtering and normalising to be useful





Block Diagram



Current Implementation

- ProSpeckZ devices sample data
  - Raw data sent to a PC over radio link
- PC runs Java program to handle data and visualisation
  - Incoming data sent to RigidBody objects representing body segments
  - Position updates signalled through events
  - Visualisation also listens to update events
- Same function as block diagram but easier to program

Problems

- Demo system lacks some calibration options
  - Aligning sensor frame with the limb segment
  - Offset and scaling co-efficients must be calculated offline and hard programmed
- Filter delay
  - Current FIR filters introduce a group delay of ~100mS
- Linear accelerations introduce significant errors

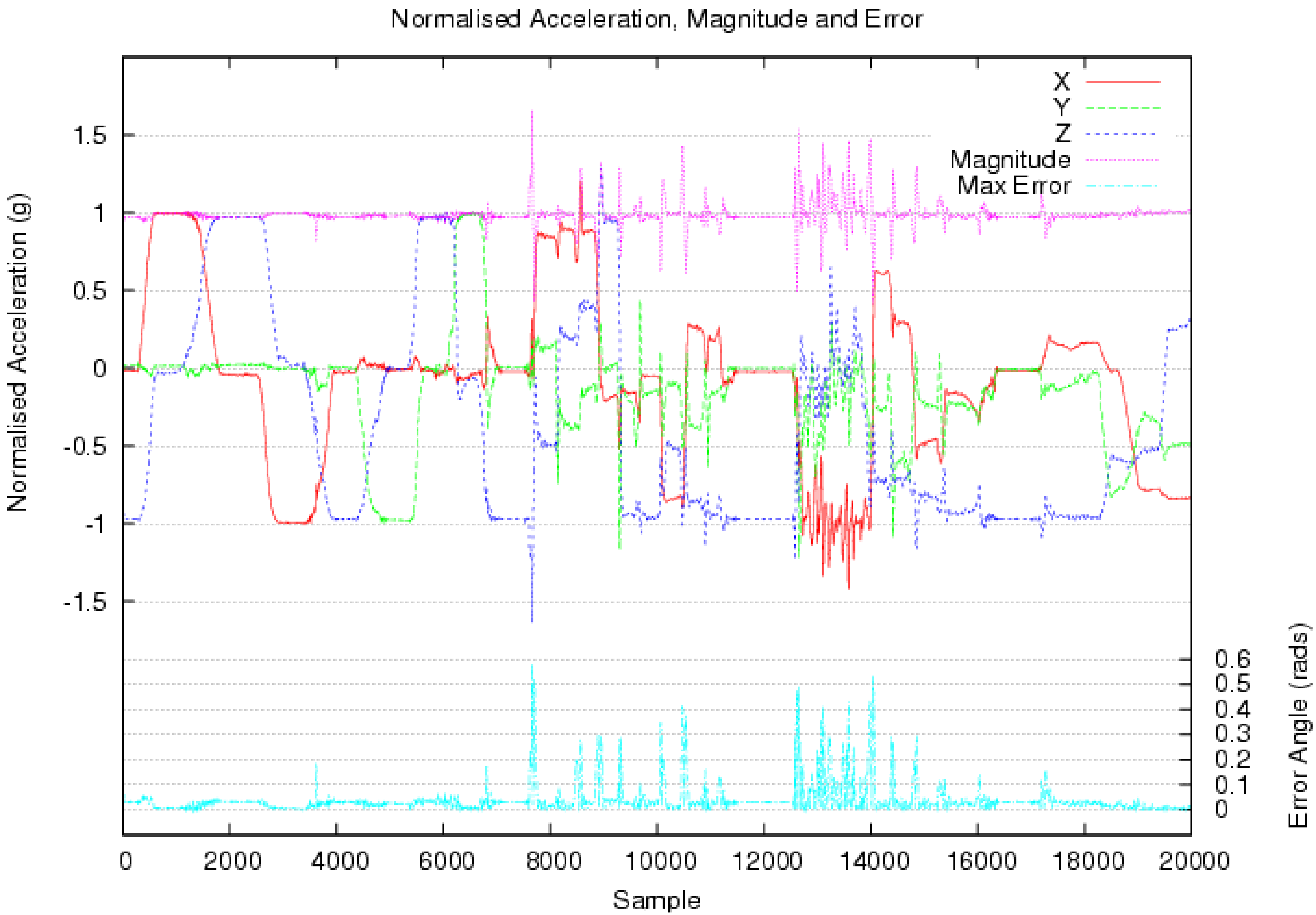
Filter Delay - Possible solutions

- Predictive Filters e.g. Kalman Filter
  - Attempts to predict future output samples from dynamic model and previous input
  - Complex
- Complementary Filters
  - Use two measurements of the same value from different sources - e.g. Accelerometer and Gyroscope
  - One input is high-pass filtered while the other is low-pass filtered
  - Cross-over frequency allows sensor confidence to be weighted

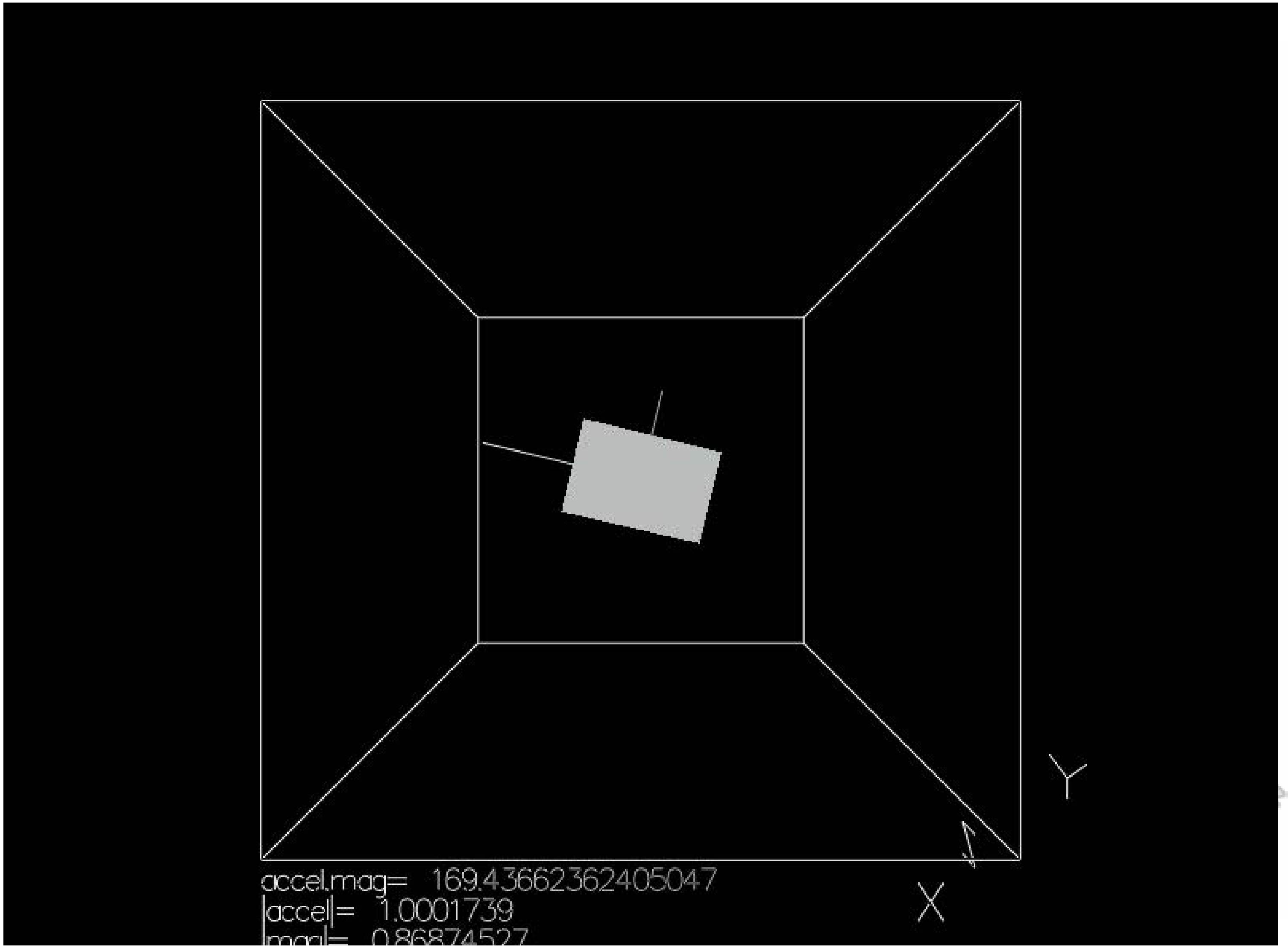
Effect of Acceleration Errors

- Measured acceleration is the vector sum of gravity and linear accelerations
- Maximum error = 180°
  - Linear acceleration > 1G
- Typical worst case error = arctan(accel)
  - Occurs when acceleration is orthogonal to gravity
- Complementary filter system using gyroscopes may overcome this problem

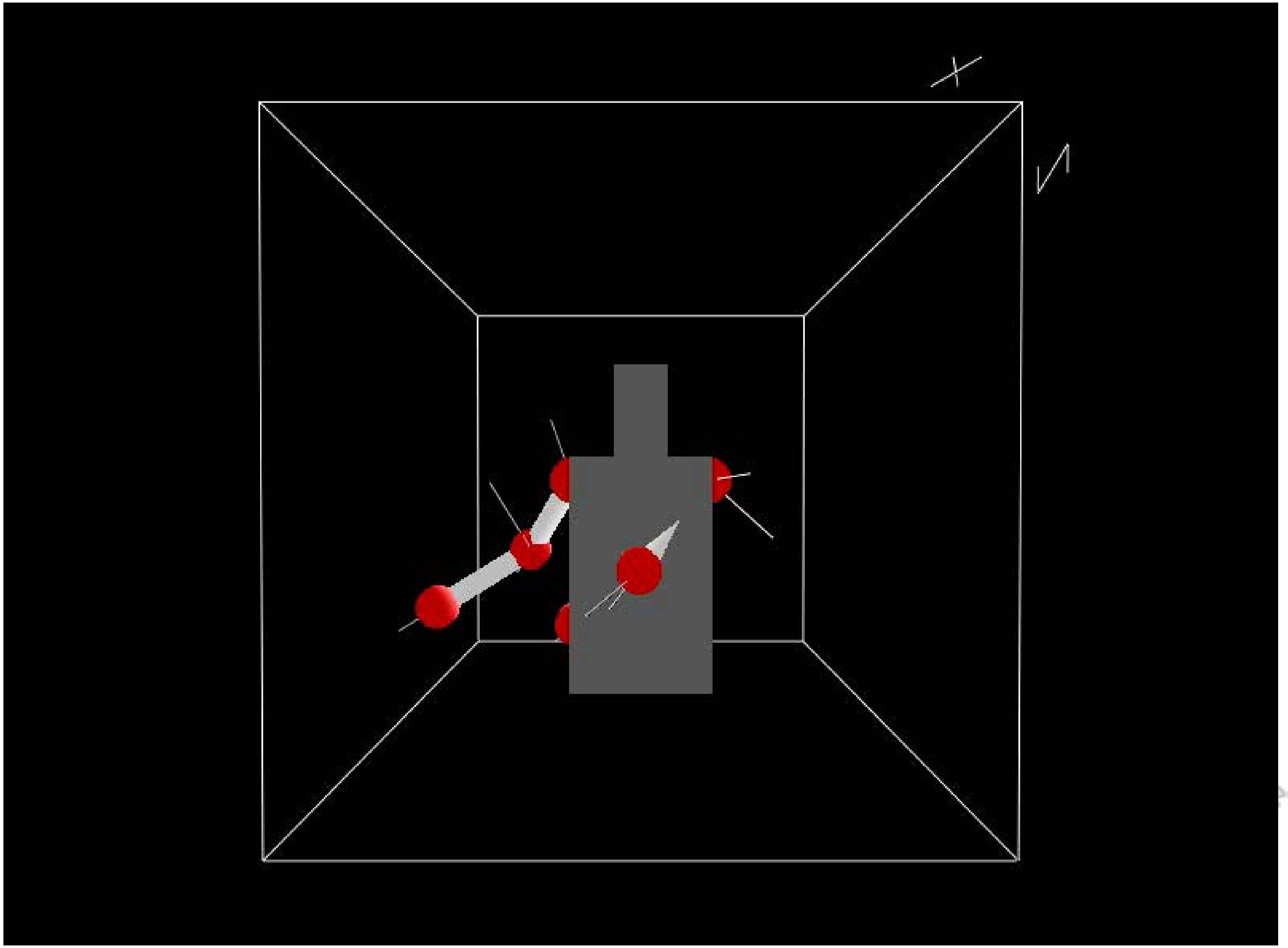
Effect of Acceleration Errors



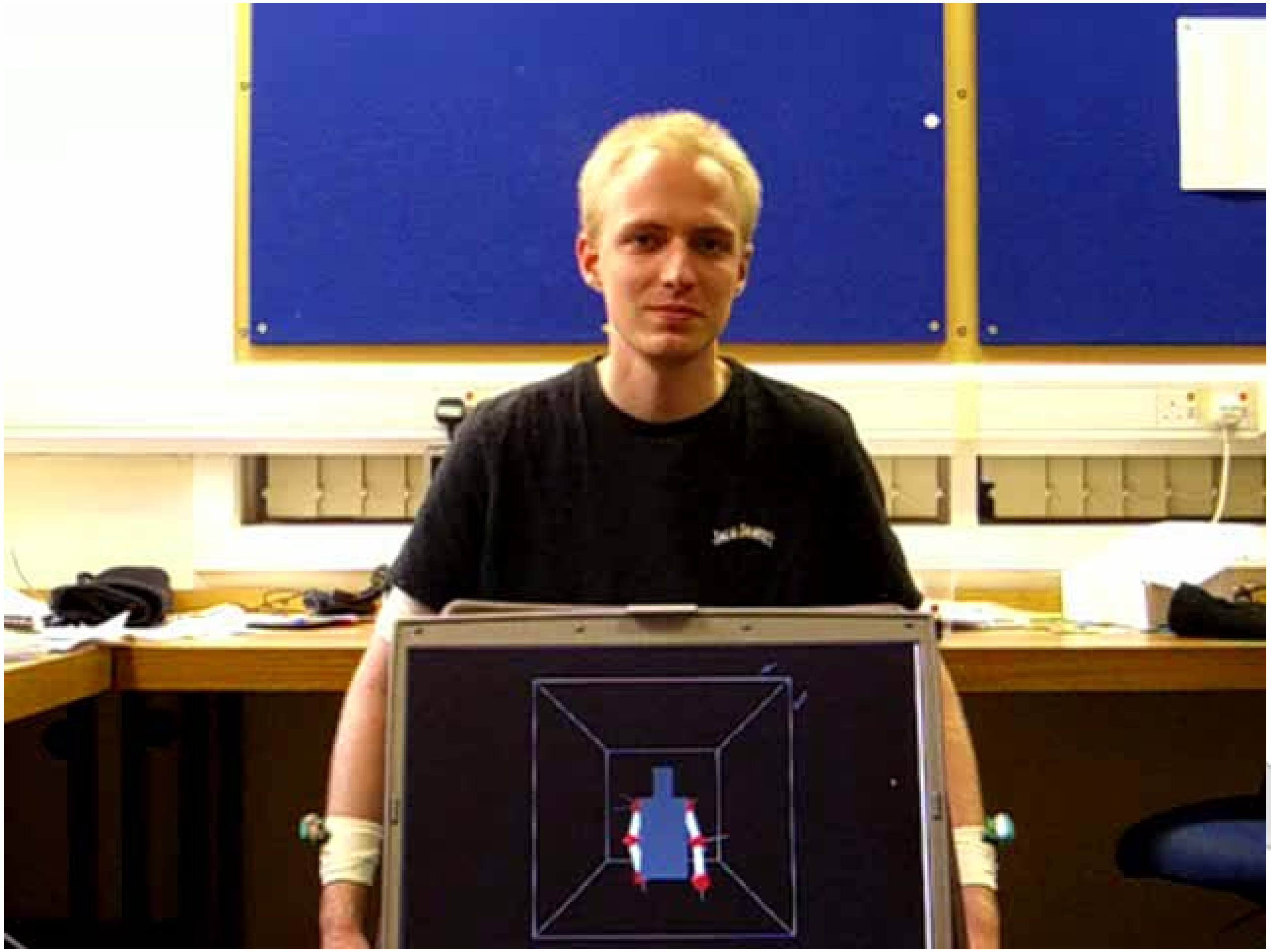
Video – 3D Compass



Video – Posture Tracking



Video – Posture Tracking 2



Questions