Comparison of linear accelerations from three measurement systems during "reach & grasp"

S.B. Thies*, P. Tresadern, L. Kenney, D. Howard, J.Y. Goulermas, C. Smith, J. Rigby
Centre for Rehabilitation and Human Performance Research, University of Salford, Salford, UK
www.healthcare.salford.ac.uk/crhpr; www.healthyaims.org

INTRODUCTION

ACCELEROMETRY

Applications

- Movement classification[1]
- Assessment of balance impairments[2]
- Identification of fall risk[3]
- Control of Functional Electrical Stimulation (FES) devices[4]

Advantages

- Inexpensive
- Easy-to-use
- Monitoring outside the laboratory: greater variety of tasks in the "real world"
- Unsupervised monitoring

Accelerometers: supplement or alternative to 3D camera systems? Interchangeable?

Objective

To compare accelerations obtained from two commercially available inertial sensors (Xsens, Kionix) with those derived from Vicon position data.

To discuss sources of error and systematic error removal.

METHODS

Experiment

Subject: healthy young adult
Object: light plastic glass
Task components:

- Reach & grasp
- Manipulate
- Release & retract

Instrumentation

On both, forearm & upper arm, aligned:

- Xsens inertial measurement unit
- Kionix accelerometer
- Reflective marker cluster

Data were sampled at 100 Hz and synchronized post data collection.

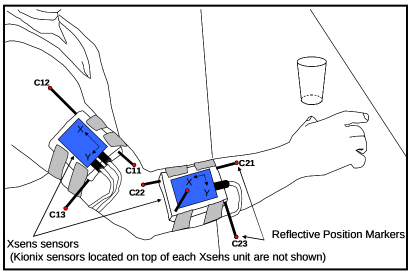

Fig.1: Experimental set-up showing marker clusters and accelerometers.

Data Processing

- Low-pass filtering of Vicon data (4th order Butterworth filter, f_c = 6 Hz)
- Double differentiation of C_{11} and C_{21} in global coordinates, adding gravity to the vertical acceleration component
- Rotation of C_{11} and C_{21} accelerations to accelerometer coordinates:

$$X_{Upper\ Arm} = (C_{12}-C_{11}) / ||C_{12}-C_{11}||$$
$$V_{Upper\ Arm} = (C_{12}-C_{11}) \times (C_{13}-C_{11})$$
$$Y_{Upper\ Arm} = V_{Upper\ Arm} / ||V_{Upper\ Arm}||$$
$$Z_{Upper\ Arm} = X \times Y$$

$$R_{Upper\ Arm} = [X_{Upper\ Arm}\ Y_{Upper\ Arm}\ Z_{Upper\ Arm}]$$

$$X_{Forearm} = (C_{22}-C_{21}) / ||C_{22}-C_{21}||$$
$$V_{Forearm} = (C_{22}-C_{21}) \times (C_{23}-C_{21})$$
$$Y_{Forearm} = V_{Forearm} / ||V_{Forearm}||$$
$$Z_{Forearm} = X \times Y$$

$$R_{Forearm} = [X_{Forearm}\ Y_{Forearm}\ Z_{Forearm}]$$

Statistical Analysis

- Pearson's Correlation Coefficient (r)
- RMS Error (€)

RESULTS

Upper Arm

r : 0.947-0.998
€: 0.22-0.42 m/s^2

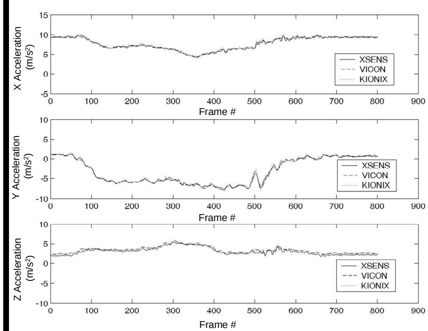

Fig. 2: Acceleration data obtained for the upper arm (sample trial).

Forearm

r : 0.989-1.000
€: 0.23-0.78 m/s^2
→ high errors were obtained for comparison of the Kionix device with Xsens (0.76 m/s^2) & Vicon (0.78 m/s^2) due to gain offset.

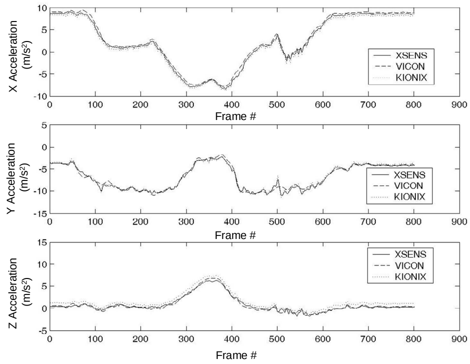

Fig. 3: Acceleration data obtained for the forearm (sample trial).

DISCUSSION

- Accelerometer data closely approximates accelerations derived from Vicon position data. Accelerometers are a good alternative when measuring segmental accelerations.
- Standard filtering procedure of position data reduced levels of noise below those of the accelerometers
→ simulating accelerometers with 3D camera systems requires an estimate of noise to be added to the signal.
- Misalignment increases RMS error. Systematic error (gain & zero offset) can be reduced with a least squares fit:

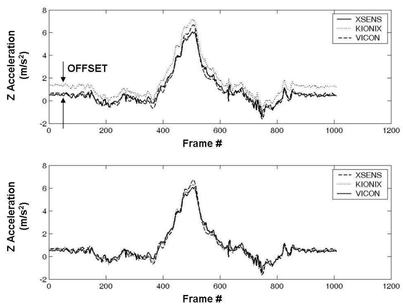

Fig. 4: Comparison of Kionix to Xsens & Vicon after offset removal: €<0.2 .

REFERENCES

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* s.thies@salford.ac.uk