

Validation of estimated orientation from inertial measurement units with an optical tracking system

Vidhya Lakshmanan^{1,2}, Roushanak H.Hassani^{1,2,3}, Thomas Seel³, Marc Bolliger², Georg Rauter¹

¹BIROMED-Lab, Dept. of Biomedical Engineering, University of Basel, ²Movement Laboratory, Balgrist, Zurich, ³FAU Erlangen-Nürnberg

Motivation

- Compare and validate wearable sensor kinematic gait parameters with the existing gold standard.

Optical Motion Capture (OMC)

- Position data
- Gold standard



- Bulky and Expensive
- Limited to gait lab
- Require specialized professionals
- Post processing



Inertial Motion Capture (IMC)

- Portable
- Easy configuration
- Not limited to gait labs



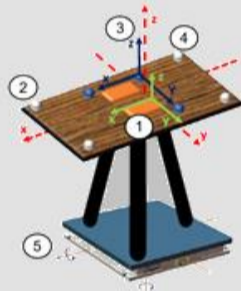
- Disturbances
- Drift over the time
- High level computation



Fig.1 OMC vs. IMC

State of the art

- Experiment was based on known orientation and rotation in predefined speeds.
- All the algorithms analysed showed reasonable results (delta rms errors < 6.4°) [1].



Materials and Methods

Step 1: 3D printed casing

- Set of 16 3-D printed casing (Fig.1) – each with 3 markers and one IMU. Synchronous data recording in full body OMC (VICON, United Kingdom) and IMC (Ultium EMG, Noraxon U.S.A. Inc.) set up.

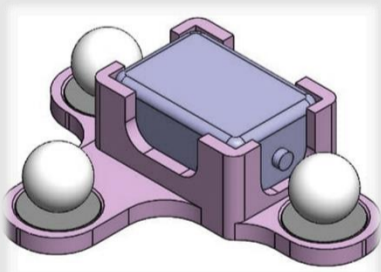


Fig.2 3-D printed casing

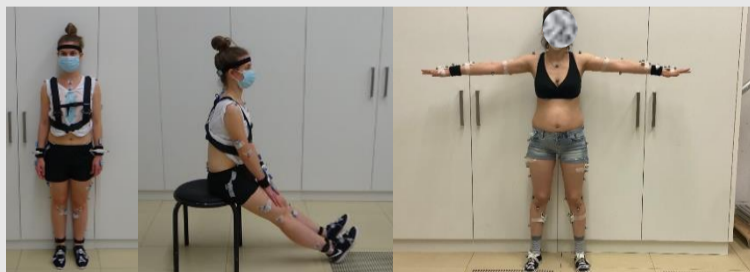


Fig.3 Calibration positions

Step 2: Data acquisition

A total of 9 healthy controls (HC)s and 3 Spinal Cord Injured (SCI) patients were measured as follows:

- Calibration measurements (Fig.3).
- Walking with a left or right U-turn.
- Walking in shape of eight (1 minute).
- Walking on treadmill (2 minutes) in preselected speed.

Step 3: Orientation validation

Orientation validation methods

OMC	IMU
Singular value decomposition [2]	Sensors fusion using strapdown integration [3]

Results

Decomposition of estimated orientations from IMC and OMC setups:

$$\mathbf{q} = \{\phi @ j\} \otimes \{\vartheta @ k\}$$

ϕ - heading angle, ϑ - inclination angle, j - horizontal axis, k - perpendicular axis to j.

Inclination and Heading angles – Delta RMSE

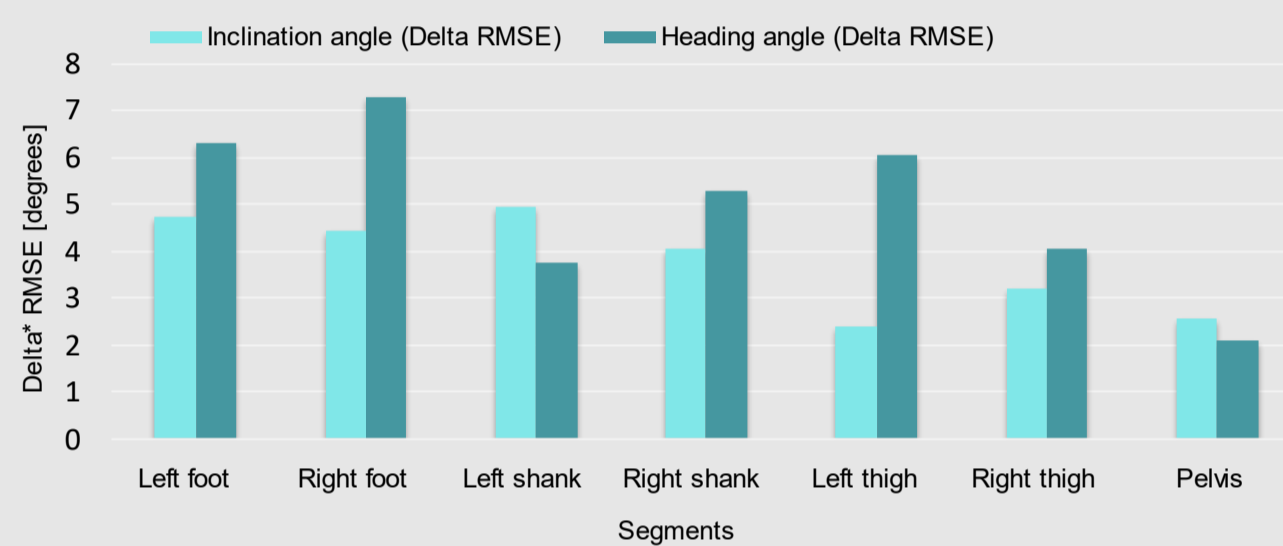


Fig. 5 Estimated inclination and heading angles from markers on casing

$$* (\Delta = \mathbf{q}_{IMC}^{-1} \otimes \mathbf{q}_{OMC})$$

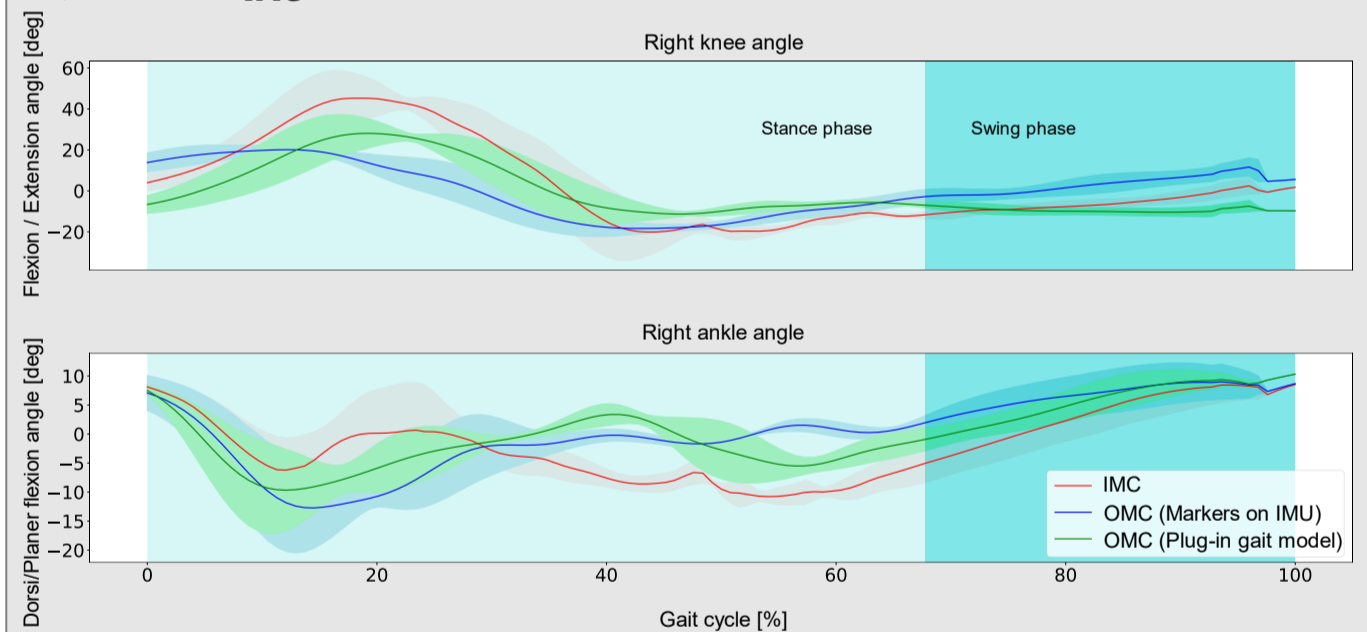


Fig. 4 Estimated knee and ankle angles (IMC, markers on casing, and plug-in gait model).

Conclusion and Future Work

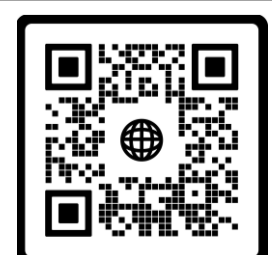
Inclination and heading angles delta RMSE on biological segments is comparatively better than the values in state of the art (delta rms errors < 6.4°).

Future Work

- Compare and validate the orientation of IMC with OMC in large number of HCs and SCI patients.
- Extend the comparison to lower limb joint angles between IMC angles, plug-in gait model, and angles calculated from markers on 3-D casing.

References:

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- A. Cappozzo, et. al, "Surface Marker Cluster Design Criteria for 3D Bone Movement Reconstruction," vol. 44, no. 44, pp. 1165–1174, 1997.
- Sabatini, A.M., 2005. Quaternion-based strap-down integration method for applications of inertial sensing to gait analysis. Medical and Biological Engineering and Computing, 43(1), pp.94-101.



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