Reliability of Integrated IMUs for Elbow-like Motion Patterns

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Integrated sensor technologies are widely used in various self-monitoring devices for leisure and professional sports activities. Vital signals and general gait information are transferred into fitness and risk levels. Additional information of the musculoskeletal system coming from inertial measurement units (IMUs) can provide important information for a better holistic interpretation.

The aim of this study was to explore the reliability (precision, accuracy and reproducibility) of the 3 rotation axes of an IMU based motion capturing system currently used by the film-industries in animated movies for future use in medical applications.

Goniometric data from the right elbow was simultaneously recorded from the IMU based motion tracking system from Noitom (Perception Legacy from Noitom Ltd.) mounted on an industrial robot arm and on five subjects and from the optical IR imaging system from Vicon (as a reference system).

Vicon is a multi-camera infrared (IR) system using reflector balls to determine orientation in space. The Noitom system is based on 18 IMUs linked through a body model to wirelessly stream and record full body motion from head to toe.

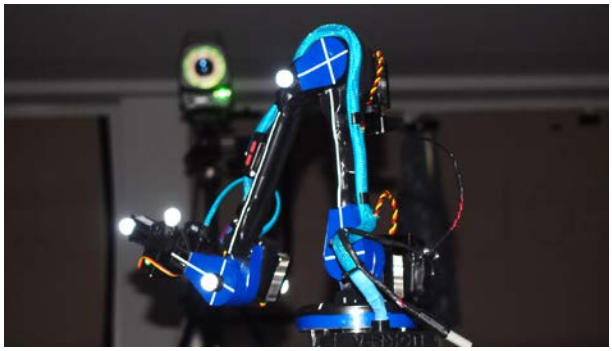

Figure 1: Robot arm with mounted reflectors and IMUs.

Using biomechanical aspects of the shoulder-elbow joints such as range of motion (ROM), velocity and orientation, a series of successive one minute motion patterns were programmed on the robot arm. The synchronized datasets were benchmarked to determine the reliability of the Noitom System compared to the gold standard Vicon.

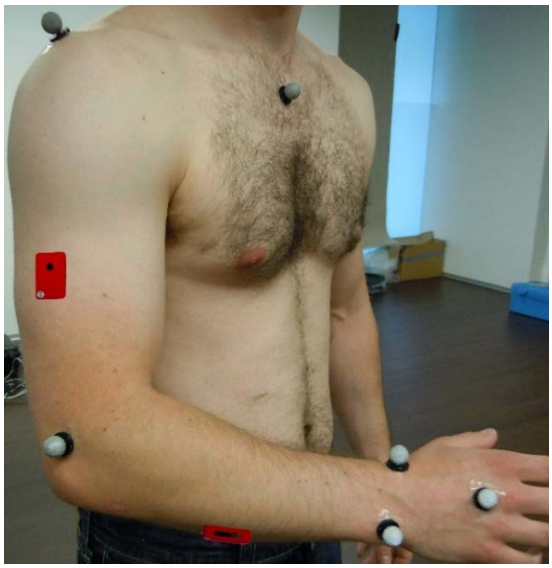

Figure 2: Subject with mounted reflectors (silver) and IMUs (red).

5% of the 166,926 collected data samples from the 5 minute robot trials were within the acceptance window of +/- 0.75°. 3% of the 111,280 collected data samples from the 5 minute human trials were within the acceptance window of +/- 0.75°. 7% of the 333,840 collected data samples from the 1 hour robot trials were within the acceptance window of +/- 1°.

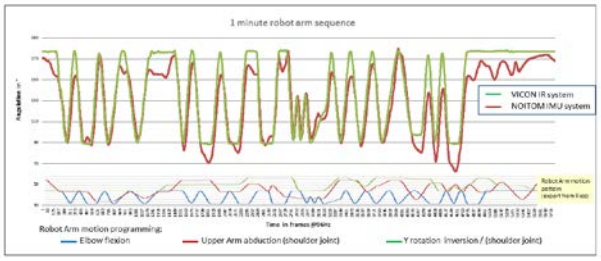

Figure 3: One minute angular data sequence showing deviation patterns between Vicon and Noitom systems.

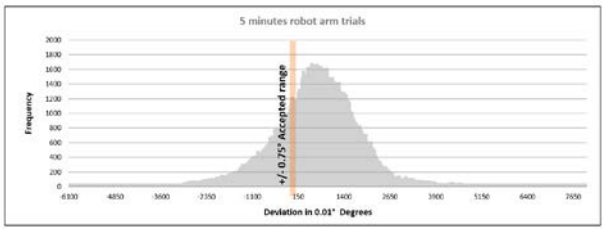

Figure 4: Histogram of 5 minute robot arm trials.

The Noitom IMU system has clear usability advantages such as working with obstacles around the subject (e.g. people, furniture), with much higher patient compliance (can be worn under clothes), with 1:10 time saving ratio on data post processing, with easier setup/equipment etc. Its current reproducibility still shows a far too high deviation rate for medical angulation monitoring over time. A distinct repetitive deviation pattern could be found on the multi axis rotation pattern. Nevertheless this lack of accuracy is still acceptable for monitoring motion patterns and detecting deviations caused by fatigue or by other systematic status changes.

The programmed motion pattern on the robot is closing the gap for a standardized approach to test the accuracy of IMUs regarding biomechanical properties of the human shoulder.

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