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3DARM

INERTIAL SENSOR-BASED 3D UPPER LIMB MOTION TRACKING AND TRAJECTORIES

Motivation

Upper limb motion tracking plays a major role in several applications such as movement evaluation of workers, gaming, human-machine interaction and medical rehabilitation. There are many systems to perform upper limb tracking – they can be non-visual (inertial), visual (with markers or marker-free) or robot-aided. Despite this variety of tracking systems, they have limitations and some of these systems also consist of specifically designed sensors and tend to be developed towards a specific goal, making them unsuitable for acting in all the applications mentioned above. Therefore, the need for a global upper limb motion tracking solution arises.

For that purpose, the 3DArm was developed. 3DArm consists in a new wearable motion tracking solution, which was built to track upper limb motion and trajectory, with applications in multiple areas.

Description

The arm motion was modelled as an articulated motion of two rigid body parts: the upper and lower segments. A total of four degrees of freedom were admitted, considering the movements caused by the shoulder and elbow joints.

Fig1. Sensors' placement and global fixed-body reference frame.

Two inertial sensors were placed on the upper and lower segments, near the elbow and wrist joints, respectively, and a global fixed-body reference frame was defined to represent the joints' position (Fig1). The sensors' orientation relative to the arm was known beforehand. A kinematic model was defined considering the shoulder joint as a fixed joint in space and only the elbow and wrist joints could be tracked.

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Features

3DArm fuses data from inertial sensors with biomechanical constraints in order to estimate orientation and find the motion trajectories of the upper limb.

Advantages

- Portable
- Low-cost
- Lightweight
- Without occlusion
- Small-sized
- Unobtrusive

Future Work

- Tracking of both upper limbs
- Tracking of the shoulder joint
- Include more biomechanical constraints
- Improve the automatic detection of sensors alignment in the arm
- Comparison with other motion tracking systems such as CODA or Qualisys

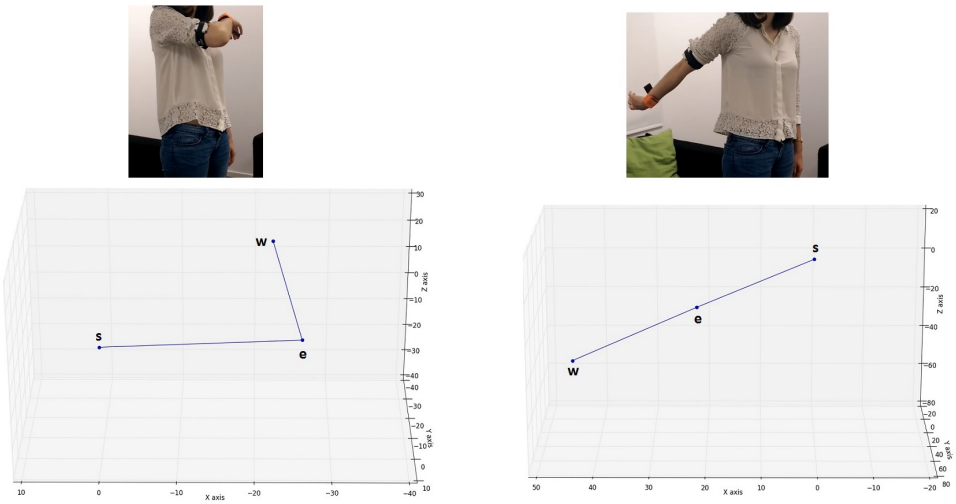

Fig2. Tracking of the elbow and wrist positions (*s*, *e* and *w* mean shoulder, elbow and wrist joint, respectively).

Data from inertial sensors were combined through an Extended Kalman Filter sensor fusion method that incorporated some biomechanical constraints of the upper limb, in order to obtain upper and lower segments' orientation relative to the global fixed-body reference frame. Then, the upper limb kinematic model was used to reconstruct upper limb motion, as depicted in Fig2.

Evaluation

To evaluate the system, 3DArm was compared to Kinect and, a maximum mean deviation of 10,60 cm and 16,33 cm for the elbow and wrist joints, respectively, were obtained. The experimental results demonstrated that the proposed tracking system had an acceptable performance, in different movements and with a tracking precision comparable to Kinect. Since the Kinect precision is sufficient to most of the tracking applications, 3DArm could be a viable alternative, with the advantages of being portable, low-cost, lightweight, small-sized and without occlusion problems.

Based on experiments, it was possible to recognize a difficulty in ensuring that the two sensors were aligned with each other when placed manually at the arm. To overcome this problem, an automatic sensor-to-body frame transformation based on a calibration movement was developed. The results showed a maximum deviation of 14 cm and 19 cm for the elbow and wrist joints between the obtained and expected positions after automatic alignment took place. Despite the position errors, the trajectories' representation was similar when sensors were manually aligned on each arm segment.

Conclusion

Despite the deviations presented, the results obtained for the 3DArm system suggest that it can be used to track upper limb motion, and can be a low-cost suitable system for different upper limb tracking applications.