Human upper body motion tracking for human-machine interaction in industrial applications

Summary

Industry 4.0 promotes the concept of automation, hence human-robot collaboration is becoming an emerging research field focused on enhancing the safety and effectiveness of human-robot systems. Accordingly, comprehensive information about human actions is essential to drive and control the robot. In light of these considerations, the aim of this Ph.D. thesis was to optimize human motion tracking for real-time applications of collaborative robotics.

Among many motion capture technologies, Inertial Measurement Units (IMUs) offer advantages in terms of wearability, low cost, portability, and freedom from laboratory constraints. Moreover, they allow reducing times of subjects' preparation and data post-processing. One of the focuses of the thesis was to assess the suitability of IMUs to capture the human movement in the industrial context. For this purpose, IMUs set-ups and related motion capture algorithms were simplified and validated. Compared to gold standards, MIMUs (Magnetic Inertial Measurement Units) produced an accurate estimate of shoulder and elbow kinematics. The same accuracy was also guaranteed when adopting IMUs and hence excluding the magnetometer from the sensor fusion process. This result allows avoiding the ferromagnetic disturbs typical of the industrial context.

Subsequently, typical industrial tasks were approached considering that their kinematics and dynamics are usually more limited and repetitive with respect to a free gesture. Since the effectiveness of collaborative robotics scenarios is also based on the identification and classification of human actions, the selection and extraction of the most relevant motion features for gesture recognition were

addressed. IMUs signals proved to be useful for procedures of motion classification. In addition, the reduction of the set-up to only one or two IMUs on the upper limb guaranteed the recognition of gestures and hence the reduction of computational times.

Finally, the know-how acquired with these parallel activities led to the necessity of modeling the human upper limb by exploiting both biomechanical and robotic knowledge. Based on this model, an IMU-driven optimal reconstruction of the human upper limb kinematics was designed, implemented, and tested in real-time applications of human-robot collaboration. At each time step, the proposed framework identifies the optimal degrees of freedom of the human arm by minimizing the difference between measured IMUs signals and the corresponding model-derived ones. The output of this process allows evaluating the orientation of the human upper body segments and hence the position of the human hand, which is released in real-time to the robot. Accordingly, collision avoidance is guaranteed, and the effectiveness of human-robot collaboration is enhanced.

Overall, the work underlined the importance of optimizing the tracking of human motion in terms of time, cost, and users' acceptance to improve collaborative robotics in the industrial context.