Human-Robot Interaction: Collaborative Robotics driven by Vision Systems

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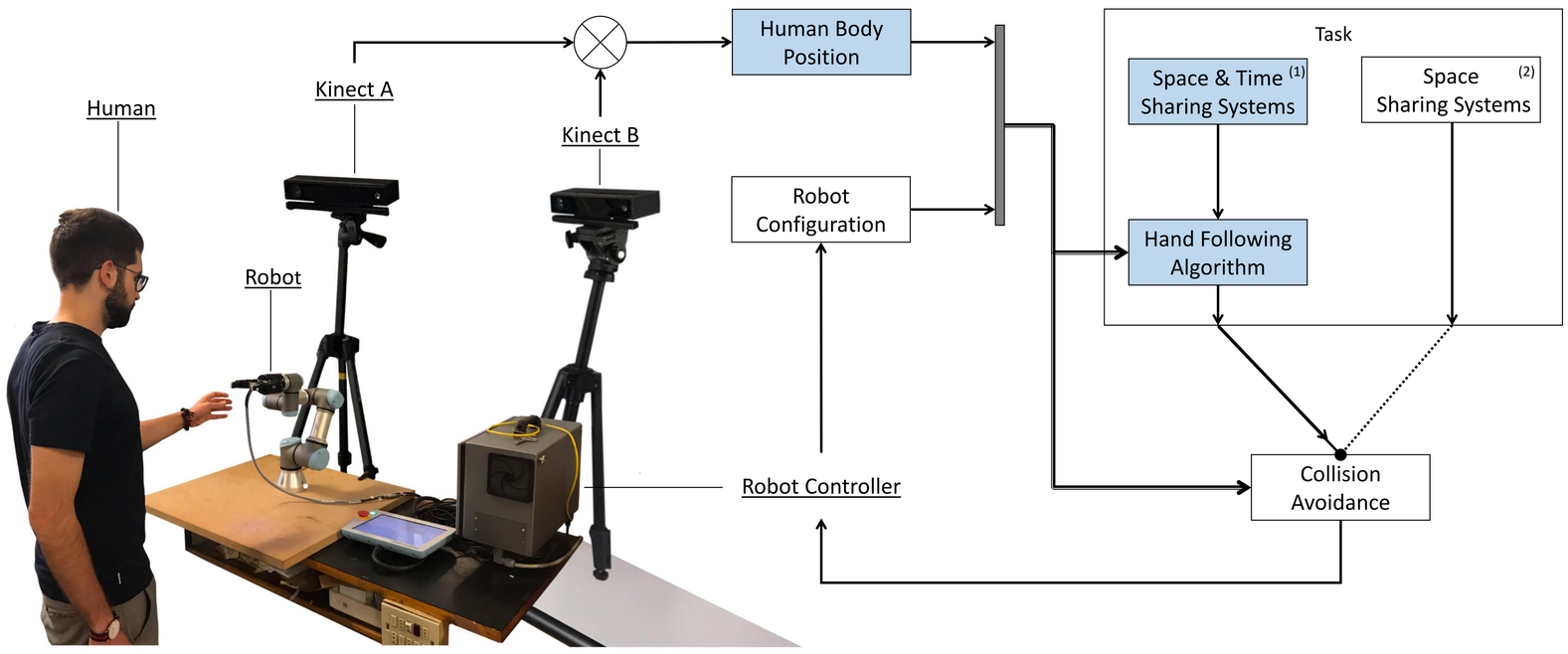
POLITECNICO DI TORINO

Introduction



Collaborative Task

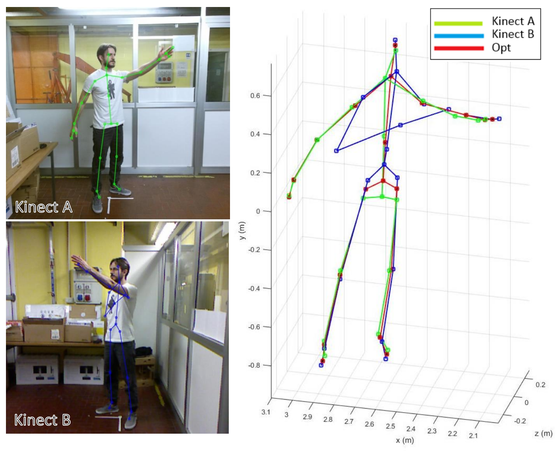
The human and the robot can share the task area with two different approaches:

1. **Space & Time sharing**: human and robot perform the task synchronizing their motion in order to meet (**hand-over**) at any time and in any point of the operational space;
2. **Space sharing:** human and robot carry out different sub-task in the same space, only being careful not to collide (**collision avoidance**).

Focus of this work

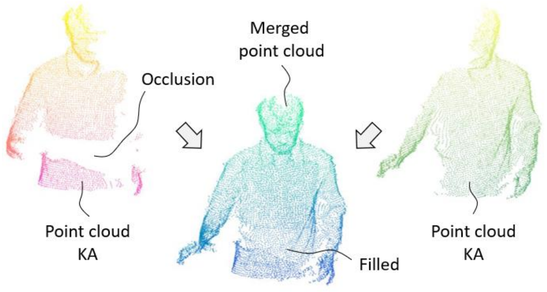
- The main purpose is to contribute to the collaborative application studying the **vision systems**, the **hand-over** task and the **hand-following** algorithm;
- in order to validate the results, experimental tests are carried out using a UR3 robot.

Human Tracking



1 *Skeleton*

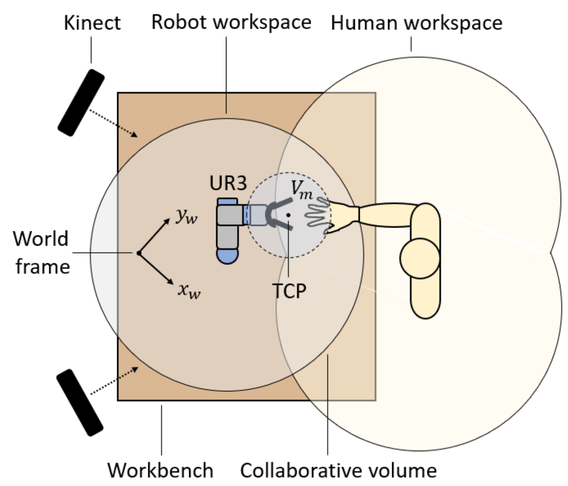
- The Kinect sensor tracks the human identifying the positions of **25 joints** (skeleton) with a sampling rate of **30 Hz**;
- **duplex Kinect** algorithm to detect the scene with different angles of view and to fill **occlusions**;
- **length** of the **bones** (skeleton links) supposed to be constant and equal to the mean value of the 2 sensors;
- the joint positions are weighted with **confidence coefficients** according to their **tracking state**;
- a **convex minimization problem** is solved to obtain the best skeleton which optimizes the joints position.



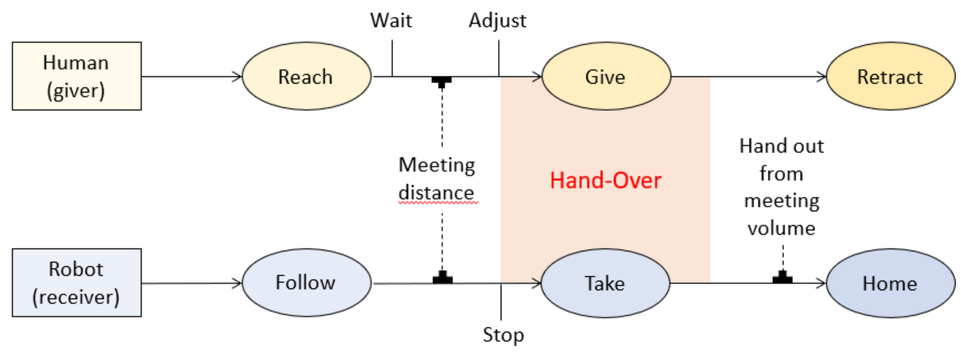
2 *Point Cloud*

- The raw data generated by the Kinect is a **point cloud** with a resolution of **512x424** with a frequency of **30 Hz**;
- **segmentation** techniques allow to extract the point cloud of the human body;
- combining the point clouds of two or **more sensors** is possible to fix **occlusions**;
- the **merged point cloud** is downsampled and denoised to speed up the computation and to eliminate the outliers respectively.

Hand-Over Task

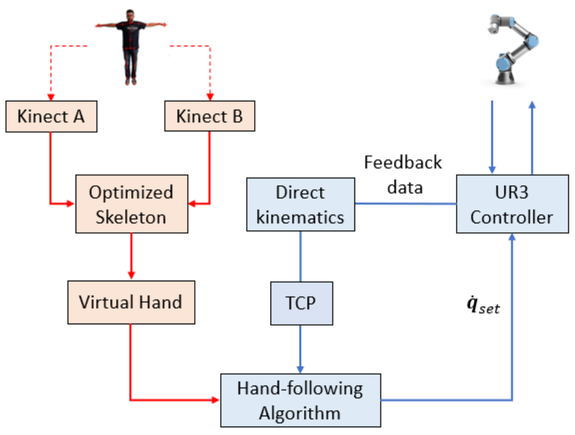


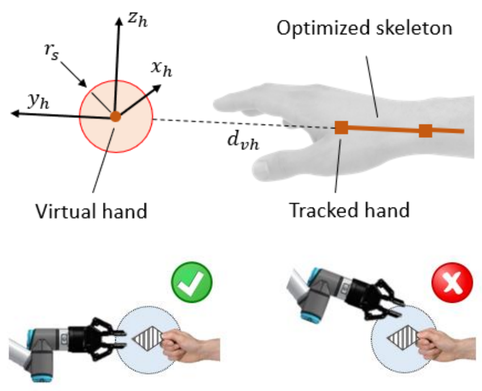
- The human hand **reaches** the **collaborative volume** V_m;
- the robot reacts and **follows** the target with its TCP;
- at a fixed **meeting distance** from the hand, the robot **stops** and **waits** for the piece;
- the human **adjusts** and **gives** the object without that the UR3 moves;
- the human **retracts** his upper limb outside of the meeting volume;
- the robot goes to his **home** position.



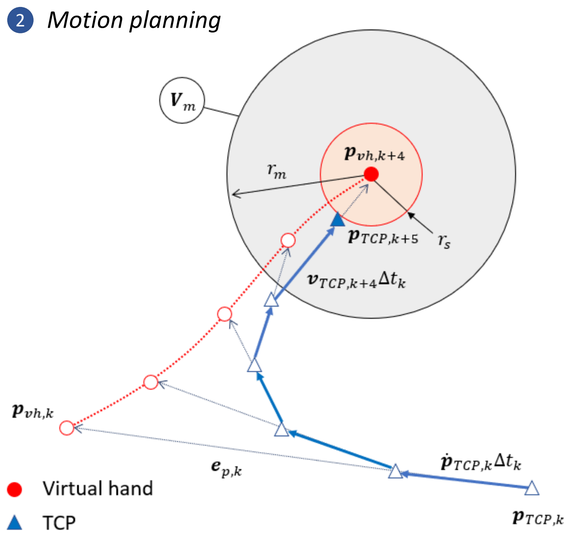
Hand-following Algorithm

1 *Block diagram*





2 *Motion planning*



Measured data from sensors:

- $\boldsymbol{p}_{vh}$: virtual hand position;
- $\boldsymbol{p}_{TCP}$: tool center point position;
- Δt_k: sampling time.

To drive the TCP towards the target:

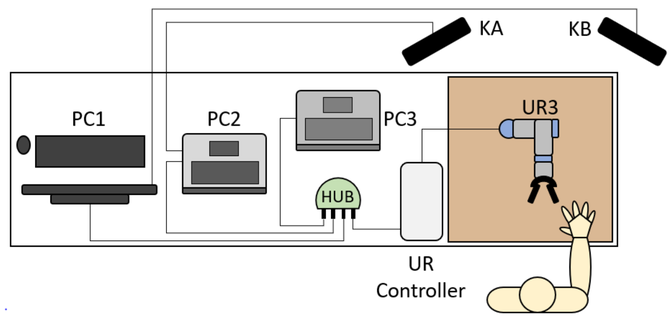
$$\dot{\boldsymbol{p}}_{TCP,k} = f(\boldsymbol{e}_{p,k}) \quad \rightarrow \quad \boldsymbol{v}_{TCP,k} = \begin{bmatrix} \dot{\boldsymbol{p}}_{TCP,k} \\ C\boldsymbol{e}_{o,k} \end{bmatrix}$$

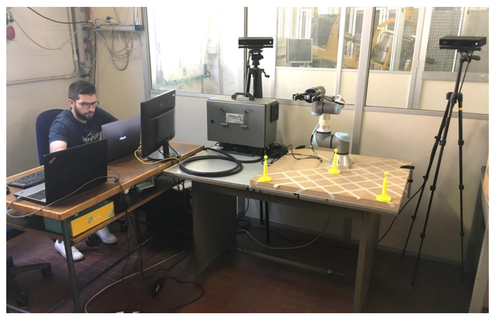
Joint velocity obtained by inverting the Jacobian:

$$\dot{\boldsymbol{q}}_k = J_k^{-1} \boldsymbol{v}_{e,k}$$

Experimental test

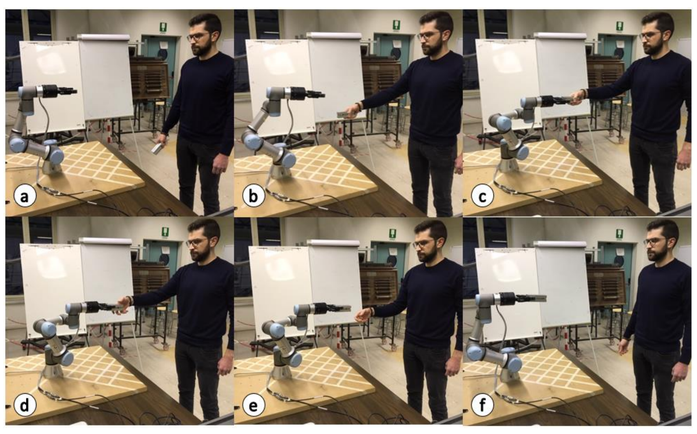
1 *Experimental Set-Up*

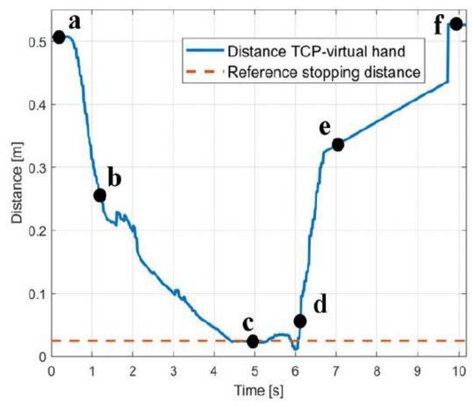




2 *Experimental Results*

Watch the video by scanning the QR code





Future Work

1. Extension of the methodology to 7 dofs robots and use of redundancy to characterize hand-over and collision avoidance applications;
2. Set-up of a full collaborative application for food industry.

Publications

1. M. Melchiorre, L.S. Scimmi, S. Mauro, S. Pastorelli: *Influence of Human Limb Motion Speed in a Collaborative Hand-over Task*. Proceedings of the 15th International Conference on Informatics in Control, Automation and Robotics, ICINCO 2018, Vol.2, 2018;
2. L.S. Scimmi, M. Melchiorre, S. Mauro, S. Pastorelli: *Multiple Collision Avoidance between Human Limbs and Robot Links Algorithm in Collaborative Tasks*. Proceedings of the 15th International Conference on Informatics in Control, Automation and Robotics, ICINCO 2018, Vol.2, 2018;
3. L.S. Scimmi, M. Melchiorre, S. Mauro, S. Pastorelli: *Experimental Real-Time Setup for Vision Driven Hand-Over with a Collaborative Robot,* International Conference on Control, Automation and Diagnosis, ICCAD 2019;
4. M. Melchiorre, L.S. Scimmi, S. Pastorelli, S. Mauro: *Collision Avoidance using Point Cloud Data Fusion from Multiple Depth Sensors: a Practical Approach.* 23rd International Conference on Mechatronics Technology, ICMT 2019;
5. L.S. Scimmi, M. Melchiorre, S. Mauro, S. Pastorelli: *Implementing a Vision-based collision avoidance algorithm on a UR3 Robot: a Practical Approach.* 23rd International Conference on Mechatronics Technology, ICMT 2019;
6. G. Quaglia, C. Visconte, L. S. Scimmi, M. Melchiorre, P. Cavallone, S. Pastorelli: Robot Arm and Control Architecture Integration on a UGV for Precision Agriculture, in Advances in Mechanisms and Machine Science, 2019;
7. G. Quaglia, C. Visconte, L. S. Scimmi, M. Melchiorre, P. Cavallone, S. Pastorelli: Design of a Positioning Mechanism of an Unmanned Ground Vehicle for Precision Agriculture, in Advances in Mechanisms and Machine Science, 2019.