Human-Robot Collaboration in Industry 5.0

MAREVA mini-project

General Context and Challenges

Human-Robot collaboration aims at combining the advantages of robots, like high speed and good repeatability, with the flexibility and adaptability of human workers. Robots can support humans when performing physically challenging tasks and at the same time allow automation in scenarios previously considered unfeasible. As a result, complex manufacturing processes can be carried out despite increasing shortage of skilled labor. The use of collaborative robots could consequently contribute to social and economic sustainability of industry.
Recently, the European Commission started a complementary approach to Industry 4.0, called Industry 5.0. It is a transformative vision of the European industry, moving toward more sustainable, human-centric, and resilient systems [1]. In this new paradigm, human-robot collaboration refers to environments, where humans and robots work in proximity, sharing their workspaces, resources, or even their tasks [2]. In such working setup new challenges arise that are related to the productivity, but also to the safety of human workers. Safety aspects are of utmost importance for the acceptance of this technology [3] and safety requirements must be met [4] [5].

Machine vision in human-robot collaboration

Although machine learning and artificial intelligence have allowed considerable advances in computer science, its industrial adoption in the domain of robotics is still in its early stages. A review of recent achievements is available in [6]. A few elementary tasks remain open: distinguishing background and objects, identifying moving objects, identifying partially covered objects, recognizing changing shapes or articulation or understanding the position and orientation of objects. All these tasks are required to enable the following paradigms:

- safety – collision avoidance (with humans and obstacles)
- coexistence – the robot capability of sharing the workspace with other workers
- collaboration – capability of performing robot tasks with direct human interaction and coordination

The presence of humans in the workspace or the random presence of objects to be manipulated introduces uncertainty that requires sensor inputs for robot control. Three sensory modalities have become dominant: vision, touch and distance, see e.g. [7]. The sensing can be used for actuation, servoing, trajectory planning, and security. Sensors can be mounted on the robot or fixed in the workspace (referred to as “eye-in-hand” and “eye-to-hand” visual servoing, respectively).

Objectives of the project (we focus on the safety) :

1) Make a literature survey on the state of the art to identify existing solutions and identify current technological barriers for ensuring the safety of human co-workers of robots.
2) Find or train a model to detect presence of humans [8],[9] and determine the position of all human body parts in the space [10]. Use low-cost sensors such as the Kinect (RGB+Depth). Convenient datasets [11] are available. The Kinect sensor can easily be calibrated.
3) Create a demonstrator using the Kinect to illustrate your results.

Project Advisor

Petr DOKLADAL : Centre for Mathematical Morphology / MINES Paris PSL petr.dokladal@minesparis.psl.fr

Pre-requisities:

1. image analysis skills, AI coding skills (tensorflow, pytorch)
2. work in team of two is possible.

Literature:

[1] Directorate-General for Research and Innovation (European Commission) *et al.*, *Industry 5.0, a transformative vision for Europe: governing systemic transformations towards a sustainable industry*. LU: Publications Office of the European Union, 2021. Consulté le: 30 novembre 2022. [En ligne]. Disponible sur: https://data.europa.eu/doi/10.2777/17322

[2] L. Wang *et al.*, « Symbiotic human-robot collaborative assembly », *CIRP Ann.*, vol. 68, nº 2, p. 701-726, janv. 2019, doi: 10.1016/j.cirp.2019.05.002.

[3] G. Michalos, S. Makris, P. Tsarouchi, T. Guasch, D. Kontovrakis, et G. Chryssolouris, « Design Considerations for Safe Human-robot Collaborative Workplaces », *Procedia CIRP*, vol. 37, p. 248-253, janv. 2015, doi: 10.1016/j.procir.2015.08.014.

[4] M. J. Rosenstrauch et J. Krüger, « Safe human-robot-collaboration-introduction and experiment using ISO/TS 15066 », in *2017 3rd International Conference on Control, Automation and Robotics (ICCAR)*, avr. 2017, p. 740-744. doi: 10.1109/ICCAR.2017.7942795.

[5] J. Fryman et B. Matthias, « Safety of Industrial Robots: From Conventional to Collaborative Applications », in *ROBOTIK 2012; 7th German Conference on Robotics*, mai 2012, p. 1-5.

[6] K. Židek *et al.*, « CNN Training Using 3D Virtual Models for Assisted Assembly with Mixed Reality and Collaborative Robots », *Appl. Sci.*, vol. 11, nº 9, Art. nº 9, janv. 2021, doi: 10.3390/app11094269.

[7] A. Cherubini et D. Navarro-Alarcon, « Sensor-Based Control for Collaborative Robots: Fundamentals, Challenges, and Opportunities », *Front. Neurorobotics*, vol. 14, 2021, Consulté le: 17 juin 2022. [En ligne]. Disponible sur: https://www.frontiersin.org/article/10.3389/fnbot.2020.576846

[8] M. Munaro, F. Basso, et E. Menegatti, « Tracking people within groups with RGB-D data », in *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, oct. 2012, p. 2101-2107. doi: 10.1109/IROS.2012.6385772.

[9] « Detecting people on a ground plane with RGB-D data — Point Cloud Library 0.0 documentation ». https://pcl.readthedocs.io/projects/tutorials/en/latest/ground_based_rgbd_people_detection.html#compiling-and-running-the-program (consulté le 13 janvier 2023).

[10] L. Seoud, J. Boisvert, M.-A. Drouin, M. Picard, et G. Godin, « Increasing the robustness of CNN-based human body segmentation in range images by modeling sensor-specific artifacts », présenté à Proceedings of the European Conference on Computer Vision (ECCV) Workshops, 2018, p. 0-0. Consulté le: 30 novembre 2022. [En ligne]. Disponible sur: https://openaccess.thecvf.com/content_eccv_2018_workshops/w18/html/Seoud_Increasing_the_robustness_of_CNN-based_human_body_segmentation_in_range_ECCVW_2018_paper.html

[11] « TIMo Dataset - Overview », *Time of Flight Dataset*. https://vizta-tof.kl.dfki.de/timo-dataset-overview/ (consulté le 30 novembre 2022).