Safe navigation and human-robot interaction in assistant robotic applications

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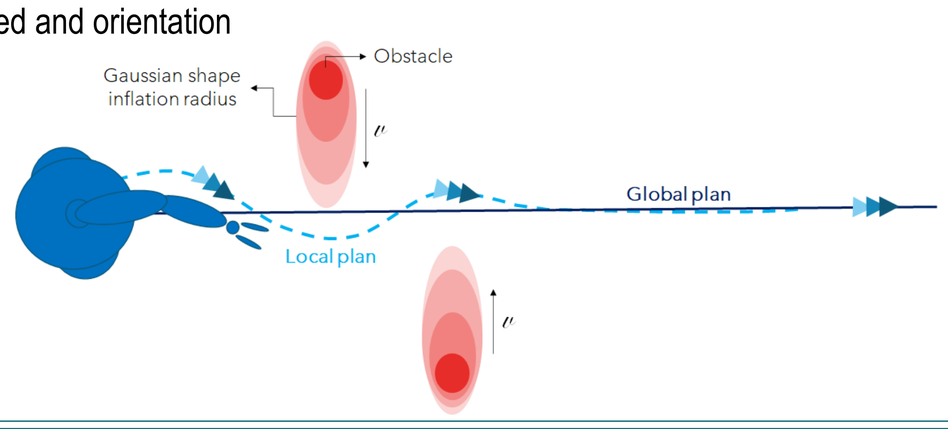
Research context and motivation

In the context of mass customization, it is envisaged that the human will increasingly have a leading role in industrial automated smart processes, since intelligent machines are still lacking cognitive skills, such as creativity and critical thinking. Human-centric oriented solutions are going to be developed based on proactive human-robot collaborations, able to better exploit the skills and capabilities of both humans and cobots, mainly thanks to artificial intelligence. The cobot takes care of the operations requiring less cognitive skills along the supply chain management and covers repetitive and routine monitoring tasks, while humans are focused on tasks requiring complex reasoning and decision-making skills. Mobile manipulators are preferrable in this context due to their dexterous mobility; however, the robot's navigation algorithm must also ensure safety in an environment shared with humans.

Adopted methodologies: Navigation

Safe navigation algorithms have been developed in ROS for mobile agents. In particular, three level of path planning have been developed, in which:

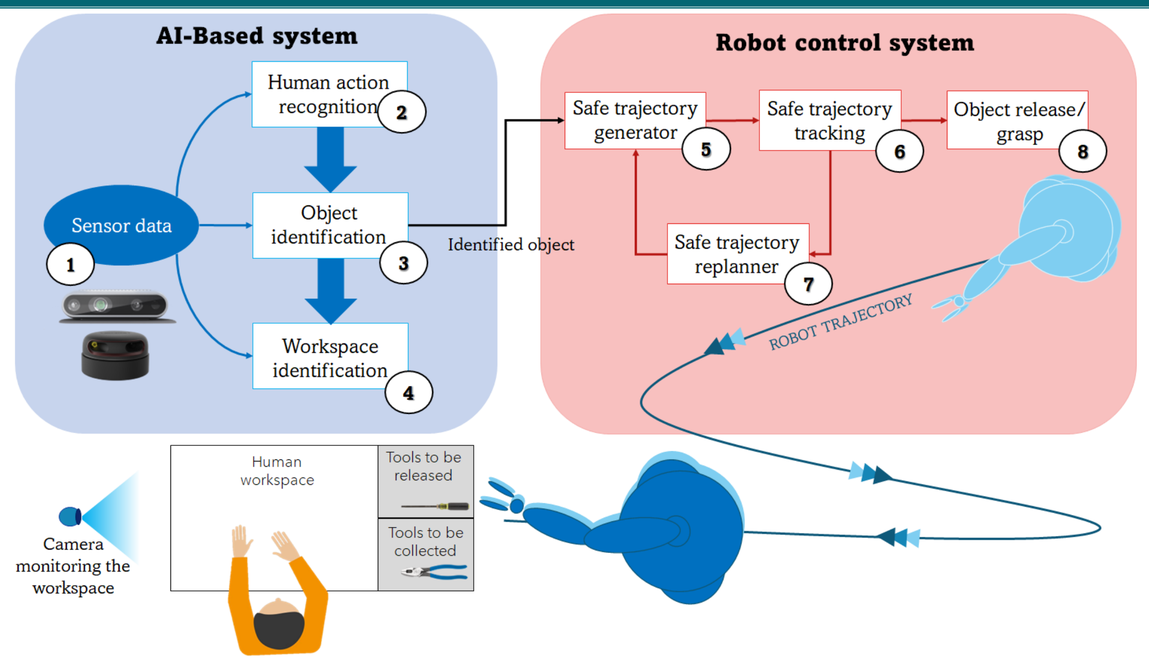
- Supervisory Global Planner (SGP): In this planning level, a desired path is computed by means of Artificial Potential Fields, the idea is that the robot should always follow the same path when is traversing an area shared with humans, due to the fact that humans may feel more comfortable and safer when it is possible to predict the motion of the robot
- Global Planner (GP): This planner interpolates the waypoints computed by the SGP, so in the absence of obstacles, the robot follows trajectory curve with the shape of the SGP
- Local Planner (LP): This planner reacts to dynamic obstacles detected within a local window provided by the sensors' field of view. Since native local planners on ROS lack of dynamic obstacle handling, a dynamic costmap layer to deal with dynamic obstacles by inflating the area around the moving object using a Gaussian shape that considers the object speed and orientation



Addressed research questions/problems

- How can the robot safely interact with the human operator?
- Is it possible to improve the awareness of the robot about its surroundings and the human actions?
- Is it feasible to develop a framework that enables the robot to learn about the human operations to be able to assist the human operator?

Adopted methodologies: Framework development



① **Sensors** are used for recognizing the human actions, tools and the workspace
② **Human actions** are identified and used to train the AI-based system in order to enable human robot prediction
③ **Tool identification** may allow the robot to grasp it correctly and deliver it in a safe manner
④ **The workspace** is divided in three areas, that separates the human working space from the robot
⑤ Once the tool is identified, **a safe trajectory** that depends on the object affordance is generated
⑥ The control system ensures the **trajectory tracking** and enable a **replanning** behaviour
⑦ when unforeseen obstacles are detected
⑧ Finally, the robot **collects or release** the tool from/to the human operator

Novel contributions

- Development of navigation algorithms for safe interaction with human operators in an industrial environment: A deterministic Supervisory Global Planner [2,4] with collision avoidance [10] along with a local planner with a dedicated dynamic obstacle handler [7]
- Identification of a framework that might enable an intuive and safe interaction between humans and robots for assistant applications [8]

Current and future works

- Development of an object manipulation algorithm for a mobile manipulator. The algorithm may gather data from different sensors of the objects and the scene so that the planned trajectory depends on the object affordance and human interaction
- Object affordance and human actions analysis should be trained using Machine Learning techniques

Submitted and published works

1. Indri, M., Sibona, F., & **Cen Cheng, P. D.** (2019, October). Sensor data fusion for smart AMRs in human-shared industrial workspaces. In IECON 2019-45th Annual Conference of the IEEE Industrial Electronics Society (Vol. 1, pp. 738-743). IEEE.
2. Indri, M., Possieri, C., Sibona, F., **Cen Cheng, P. D.**, & Hoang, V. D. (2019, September). Supervised global path planning for mobile robots with obstacle avoidance. In 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA) (pp. 601-608). IEEE.
3. Indri, M., Sibona, F., & **Cen Cheng, P. D.** (2020, September). Sen3Bot Net: A meta-sensors network to enable smart factories implementation. In 2020 25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA) (Vol. 1, pp. 719-726). IEEE.
4. Indri, M., Sibona, F., **Cen Cheng, P. D.**, & Possieri, C. (2020, September). Online supervised global path planning for AMRs with human-obstacle avoidance. In 2020 25th IEEE international conference on emerging technologies and factory automation (ETFA) (Vol. 1, pp. 1473-1479). IEEE.
5. Bonci, A., **Cen Cheng, P. D.**, Indri, M., Nabissi, G., & Sibona, F. (2021). Human-robot perception in industrial environments: A survey. Sensors, 21(5), 1571.
6. Sibona, F., **Cen Cheng, P. D.**, Indri, M., & Di Prima, D. (2021, September). PoinTap system: a human-robot interface to enable remotely controlled tasks. In 2021 26th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA) (pp. 01-08). IEEE.
7. **Cen Cheng, P. D.**, Indri, M., Sibona, F., De Rose, M., Prato, G., (2022, September). Dynamic Path Planning of a mobile robot adopting a costmap layer approach in ROS2. In 2022 27th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2022). IEEE. (In press)
8. **Cen Cheng, P. D.**, Sibona, F., Indri, M. (2022, September). A framework for safe and intuitive human-robot interaction for assistant robotics. In 2022 27th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2022). IEEE. (In press)
9. Sibona, F., **Cen Cheng, P. D.**, Indri, M. (2022, September). How to improve human-robot collaborative applications through operation recognition based on human 2D motion. In 2022 48th Annual Conference of the Industrial Electronics Society (IECON 2022). IEEE. (In press)
10. **Cen Cheng, P. D.**, Indri, M., Possieri, C., Sassano, M., Sibona, F. (2022, September). Path planning in formation and collision avoidance for multi-agent systems. Nonlinear Analysis: Hybrid Systems, 2022. (In press)

List of attended classes

Hard Skills (Politecnico di Torino)

01UMNRV - Advanced deep Learning (didattica di eccellenza) (15/06/2021, 30h)
01UIHIW - Advanced numerical modeling for systems engineering: theory and applications (16/09/2021, 20h)
01UJBRV - Adversarial training of neural networks (01/07/2020, 15h)
01UJTIU - Control and data acquisition automation in scientific experiments (25/06/2020, 10h)
01LCPRV - Experimental modeling: costruzione di modelli da dati sperimentali (14/07/2020, 33h)
01QSAIU - Heuristics and metaheuristics for problem solving: new trends and software tools (10/07/2020, 20h)
01UXLIU - Object detection for automotive and aerospace applications: reliability challenges and solution (didattica di eccellenza) (12/10/2020, 15h)
01SFURV - Programmazione scientifica avanzata in matlab (29/06/2020, 28h)

Soft Skills (Politecnico di Torino)

02LWHRV - Communication (04/12/2019, 5h)
01UNRRV - Entrepreneurship and start-up creation (03/07/2020, 40h)
01RISRV - Public speaking (10/12/2019, 5h)
01SWPRV - Time management (06/12/2019, 2h)
01QORRV - Writing Scientific Papers in English (20/02/2020, 15h)

Hard Skills (External courses/activities)

- Computing@PoliTO Workshop - HPC/Big Data/Cloud for Research (17/01/2020, 5h)
- SIDRA 2021 PhD Summer School - Bertinoro University Residential Centre (12/07/2021, 30h)
- DISC Summer School Planning, Learning and Control for Multi-Robot and Multi-Agent Systems - Dutch Institute of Systems and Control - Utrecht (08/06/2021, 24h)
- PhD course Hybrid Systems - Politecnico di Milano (Italy) (25/01/2021, 25h)
- PhD course Model Predictive Control - Scuola IMT Alti Studi Lucca (Italy) (01/04/2022, 20h)