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XXXVII Cycle

Autonomous Navigation for Service Robotics

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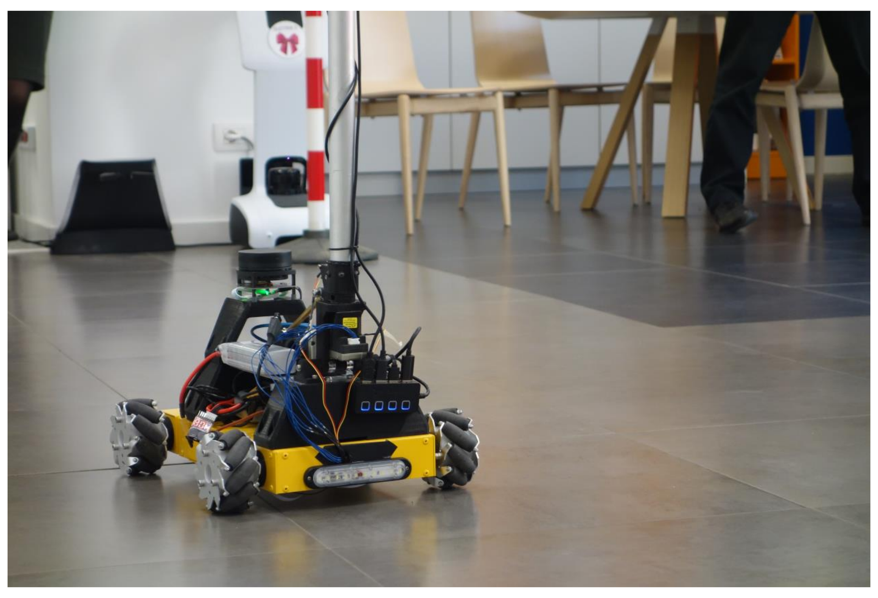
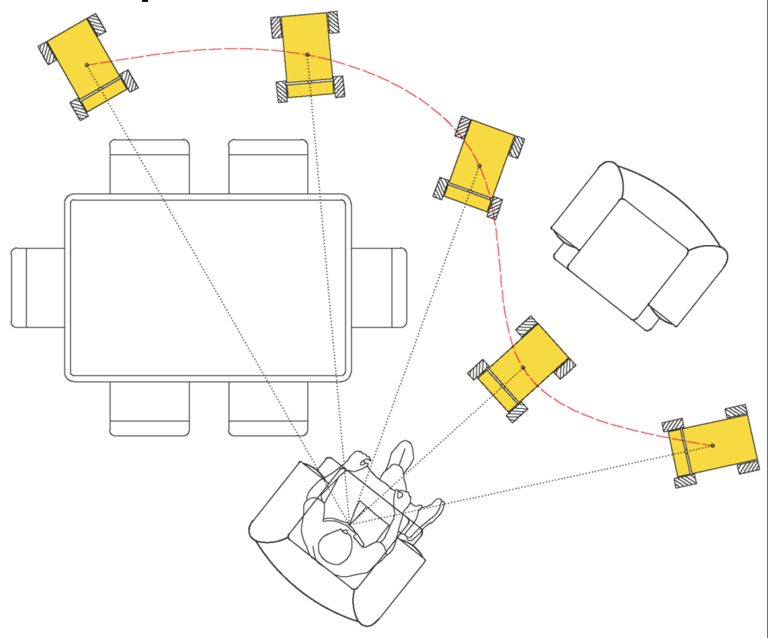
Research context and motivation

- Robot assistants are emerging as high-tech solutions to support people in everyday life. A wide range of human assistive robotic tasks require the robot to autonomously follow the user in unstructured, dynamic environments and simultaneously **combine goal-based motion planning and person monitoring**.
- The navigation system should be as robust and reliable as possible. This security is often achieved with traditional, heuristic controllers, such as **Dynamic Windows Approach** (**DWA**), and classic path planners, like **A*** or **Dijkstra** algorithms, since they are perceived as more stable and reliable compared to machine learning methods, which are relegated only to perception and computer vision tasks.



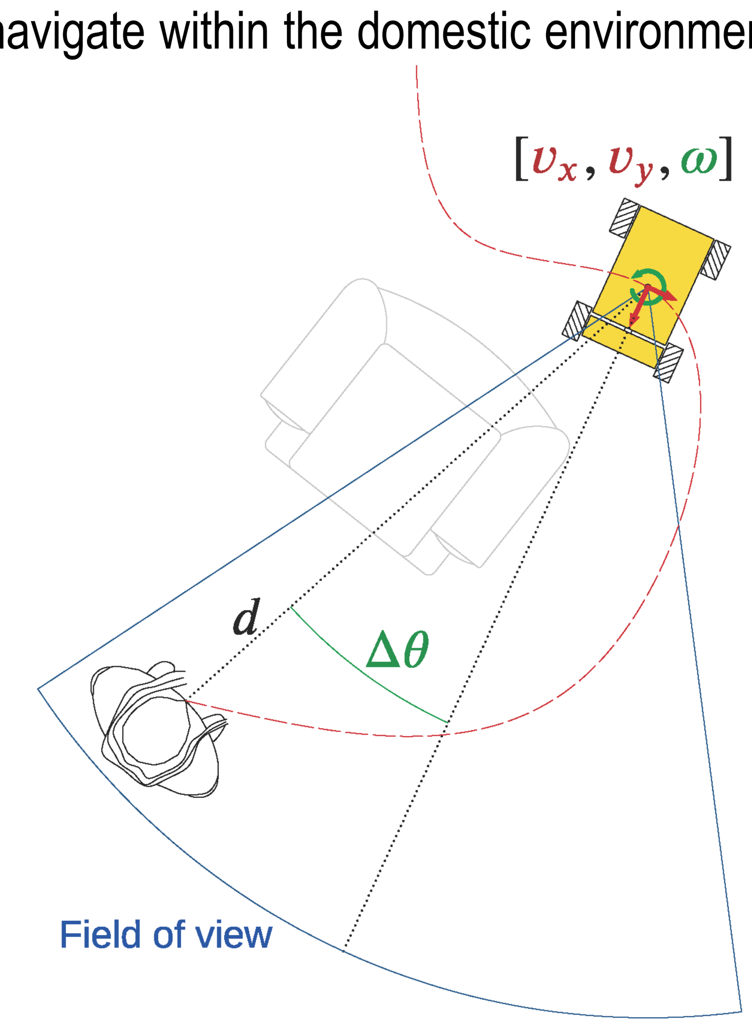
Addressed research questions/problems

- Although they are still considered less reliable, **Deep Reinforcement Learning** (**DRL**) solutions are evolving and becoming more and more robust. One of the last researched compromise is the **integration of traditional and machine learning algorithms**, in order to obtain innovative and effective systems.
- In this scenario, one of the main challenge in human-centered navigation is to constantly maintain the focus of the monitoring system, mounted on the robotic platform, toward the user. This often means **keeping the orientation of the platform towards the user**, to maintain them in the camera field of view.
- However, this is not always possible with classic, differential drive platforms, since they can't describe a curved motion without a change in orientation. This often leads to lose the human target while avoiding obstacles or following an occluded path. Therefore, it is clear that maintenance of a certain desired orientation and collision-free navigation towards a precise destination result in conflicting objectives.



Novel contributions

- We introduce a new approach to **human-centered navigation** for assistance and monitoring. Our methodology exploits an omnidirectional robotic platform to detach the computation of linear and angular velocities and navigate within the domestic environment without losing track of the assisted person.
- The omnidirectional robot can handle its motion along all directions of the horizontal plane without the necessity to change its orientation. This means it is possible to entrust linear velocities only to a classic DWA controller, while a second navigation module manage the yaw angular velocity, to maintain the orientation of the platform towards the user at every time instant.
- The final objective is to maintain the value of $\Delta\theta$ between the orientation of the rover and the orientation of the vector connecting the rover's center of rotation with the person position as small as possible.



Submitted and published works

- **Eirale, A.**, Martini, M., Tagliavini, L., Gandini, D., Chiaberge, M. and Quaglia, G., 2022. "*Marvin: An Innovative Omni-Directional Robotic Assistant for Domestic Environments*", Sensors, 22(14), p.5261
- **Eirale, A.**, Martini, M., Chiaberge, M., 2022. "*Human-Centered Navigation and Person Following with Omnidirectional Robot for Indoor Assistance and Monitoring*", Submitted to Robotics
- **Eirale, A.**, Martini, M., Chiaberge, M., 2022. "*RL-DWA Omnidirectional Motion Planning for Person Following in Domestic Assistance and Monitoring*", Submitted to ICRA 2023

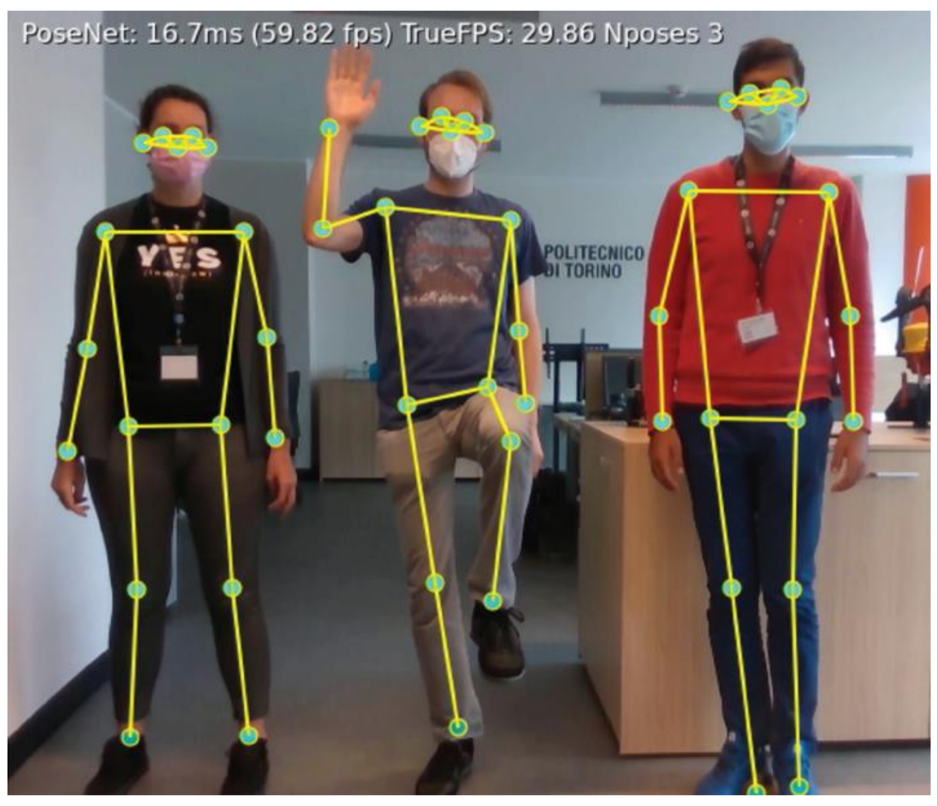
Adopted methodologies

DRL agent training

- Linear velocities [x_v, y_v] are managed by a DWA controller, capable of generating obstacle-free trajectory towards the goal
- To maintain the orientation of the platform towards the user, we train a Deep Reinforcement Learning agent able to control the angular yaw velocity [ω].
- The DRL agent input features embed the necessary information about the dynamic goal, as the distance from the goal d_t, the angle $\Delta\theta$ and the velocity at the previous time instant ω_{t-1}.
- We define a reward function r_h as the arithmetic sum of two distinct contributions. The first teaches the agent to maintain its orientation towards the goal, while the second contribute is used to obtain a smooth transition between the current agent's yaw velocity output and that at the next time instant.
- The agent is trained in a novel simulation environment resembling a domestic scenario, and presenting several different obstacles.

Deployment on real platform

- An innovative perception pipeline based on **PoseNet** and **Sort** is exploited to localize and track the person in the environment, to extract the goal position.
- The whole system is tested in a cluttered environment, featuring different low obstacles, tracking both the followed person and the rover with a novel **UWB localization framework**.
- Our omnidirectional solution is compared with a differential drive configuration, to validate and show the competitive advantage of our methodology.



Future work

- Further exploration of **hybrid DRL-based planner** for indoor assistance, such as **person accompany**
- Novel DRL-based navigation policy for **tunnel exploration and reconnaissance**
- **Adaptive DRL policy planner** for navigation in cluttered and complex environment
- Convolutional Neural Networks for **Room Recognition of indoor Domestic Scenarios**

List of attended classes

- 01UJBRV – Adversarial training of neural networks (6/6/2022, 3)
- 01TUFRV – All you need to know about research data management and open access publishing (12/4/2022, 3)
- 01QTEIU – Data mining concepts and algorithms (3/2/2022, 4)
- 01SHMRV – Entrepreneurial Finance (15/9/2022, 1)
- 01UJUIU – Human-Ai Interaction (9/2/2022, 4)
- 01SCSIU – Machine learning for pattern recognition (22/7/2022, 4)
- 01UNVRV – Navigating the hiring process: CV, tests, interview (20/12/2021, 1)
- 01DNMIU – Optimized execution of neural networks at the edge (5/9/2022, 5)
- 01UNYRV – Personal branding (20/12/2021, 1)
- 01SYBRV – Research integrity (14/9/2022, 1)
- 01UNXRV – Thinking out of the box (14/9/2022, 1)
- 01QORRV – Writing Scientific Papers in English (5/5/2022, 3)

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