"Robots learn to behave: improving human-robot collaboration in flexible manufacturing application"

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Summary

Over the past decades, industrial revolutions hinted to future fully automated scenarios, where humans would have taken on the role of mere supervisors. However, the need for mass product customization, rather than mass production, has led to a new concept of production line, where robots share workspaces with humans. The solutions envisaged by Industry 5.0 are *human-centred* and flexible manufacturing setups, where fixed-base and mobile robots collaborate with humans. This interaction has yet to become smooth given the difference in cognitive capabilities. Hence, to teach robots the correct and safe behaviour during collaboration, artificial intelligence can be leveraged to enable operation recognition and allow for learning.

The research work focused on the evolution of differential drive mobile robots from human-free to *human-shared workspace*. In particular, to implement a robot able to cooperate and collaborate with human operators, an Autonomous Mobile Robot (AMR) demonstrator has been made capable of:

- representing a support for Automated Guided Vehicle (AGV) networks
- following a supervised safe path generated exploiting attractive curves and barrier functions, using a modified version of the A* global planner
- detecting human obstacles, through a state-of-the-art neural network-based object detection algorithm, so as to overcome them conservatively
- triggering the online re-computation of global plans to follow the safe curve when a human is detected

Then, with the aim of enabling robot learning to improve collaboration the AMR has been upgraded to be able to:

- monitor the scene where the human is working
- collect data on the operator's 2D motion as map images
- use map images for training a deep neural network to learn how to recognize performed operations

Lastly, also the evolution of *fixed-based* manipulator collaborative robots (*cobots*) have been investigated. In particular the role of manipulators have been approached through:

- An interface to supervise the execution of a desired assembly task
- A concept proposal for exploiting simulation to improve interactive imitation learning.

These contributions feature the integration of open source tools, libraries and data, to come up with new solutions to tackle the challenge of improving collaborative manufacturing tasks. In particular, some contributions aim at upgrading existing networks of AGVs with new technologies represented by AMRs serving as *meta-sensors*, i.e., distributed sensors ①. Then, a data-driven framework exploiting deep learning models to recognize a human operation from map images featuring the human 2D motion demonstrates that minimal but useful results can be achieved even in case of data scarcity, exploiting data that is independent of the specific features of the operator ②.

Finally, the concept research idea enabling a fixed-based cobot to exploit simulation to regulate interactive demonstrations in *interactive imitation learning*, represents an effort towards reducing the burden on humans, with the aim of making the teaching process less demanding for the user in terms of time and expertise ③.