Ph.D. in Information Technology
Thesis Defenses

May 29th, 2025
At 9:00 a.m.
Room Alpha– Building 24

Elias MONTINI – XXXVI Cycle

ACHIEVING TRUE HUMAN-ROBOT COLLABORATION: A METHODOLOGICAL FRAMEWORK TO SOLVE CHALLENGES IN INDUSTRIAL SETTINGS
Supervisor: Prof. Paolo Rocco

Abstract:

This doctoral research addresses the mismatch between the perceived and actual use of collaborative robots (cobots) in industry. While cobots are promoted as flexible tools for collaboration, they are often used as conventional automation systems with little human interaction.
To bridge this gap, the thesis proposes a methodological framework to support the design and implementation of truly collaborative applications. The framework is based on mutual benefit and adaptability, aiming to improve both system performance and worker well-being.
The research includes a survey and an industrial case study that confirm current limitations in cobot use. It also introduces a digital human twin meta-model and a flexible IIoT platform for scalable and reusable collaborative systems.
Several applications, such as parts handling and screwdriving, demonstrate how dynamic task allocation, system awareness, and anticipatory robot behaviour can enhance human-robot collaboration. The impact on human factors like trust, workload, and anxiety was assessed through targeted experiments.
This work contributes a comprehensive, validated approach to move beyond automation and enable real collaboration between humans and robots.

Isacco ZAPPA– XXXVII Cycle

COBOTS UNDERSTANDING SKILLS PROGRAMMED BY DEMONSTRATION
Supervisor: Prof. Andrea Maria Zanchettin

The consolidation of the fourth industrial revolution brought a change of perspective on the role of robots in factories. From general-purpose machines, hard-coded for specific tasks in confined workspaces, robots are now increasingly conceived as intelligent systems able to work alongside human operators. Collaborative robots (cobots) embody this paradigm shift, offering companies safer and more interoperable machines. Besides, the programming of cobots has been made easier with user-friendly interfaces featuring a growing set of pre-programmed skills that enhance flexibility and ease of deployment. However, despite these advancements, a key barrier to widespread cobot adoption, especially among Small and Medium-sized Enterprises (SMEs), remains the need for field experts to design and validate robot operations.

This thesis aims to develop no-code programming interfaces to enable non-expert users to program cobots. Lowering the expertise required for cobot programming would not only expand their market reach but make SMEs exploit the benefits provided by such advanced technologies, bridging the gap with industry leaders.
Several strategies have been explored to provide non-experts with intuitive robot programming methods. Programming by Demonstration (PbD) enables robots to learn skills by extracting execution policies from user demonstrations. Recent advancements focus on equipping systems with semantic reasoning capabilities, allowing them to understand the meaning of demonstrated actions, thus enabling symbolic planners to reuse and arrange the skills sequence required to perform the task. However, the limited descriptive capabilities of current approaches hinder their application in realistic industrial settings. This thesis addresses this challenge by enhancing the system's semantic descriptive capabilities and extending PbD methodologies to multi-agent scenarios. Additionally, it explores alternative uses of the learnt semantic skill descriptors, proposing a methodology to segment and classify a continuous demonstration of a task into the sequence of robot skills necessary for replicating it.
Finally, the thesis focuses on improving the encoding of demonstrated trajectories. For tool-based skills such as welding and polishing, existing methods rely on waypoint savings and manual specification of movement types, increasing the programming expertise required. Addressing the issue, the thesis presents a methodology for parameterizing trajectories from continuous hand-guided demonstrations. This approach enables the system to generate robot-executable code directly from a simple user demonstration, streamlining the programming process.
All methodologies proposed in this thesis are experimentally validated via user studies involving non-experts, assessing their effectiveness as robot programming interfaces and evaluating overall system usability.

PhD Committee

Prof. Alessandro Colombo, **Politecnico di Milano**

Prof. Eren Erdal Aksoy, **Halmstad University**

Prof. Manuel Beschi, **Università degli Studi di Brescia**