PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Francesco Cufino

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-25 - PhD Year: Second

Francesco Cufino

Tutor: prof. Fabio Ruggiero

Fabio Ruggiero

Date: October 29, 2025

1. Information:

- **PhD student: Francesco Cufino** **PhD Cycle: XXXIV**
- **DR number: DR997190**
- **Date of birth: 20/03/1999**
- **Master Science degree: Automation and Robotics Engineering**
  University: Università degli studi di Napoli Federico II
- **Scholarship type: PNRR - DM 118/2023**
- **Tutor: Fabio Ruggiero**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
-Study of the state of the art of pushing manipulation through humanoid robot -Started designing a possible innovative framework for humanoid pushing a wheelchair -Contribution for experiments for non-prehensile ball catching	Research		10	01/11/2024 – 31/12/2024		
How to boost your PhD	Course	18	5	08/01/2025 – 29/01/2025	Prof. Antigone Marino	Y
-Continuation of designing a control framework for humanoid robot to push a wheelchair -Experimental activity: testing	Research		5	01/01/2025 – 28/02/2025		

humanoid robot motion and definition of the experimental setup for pushing wheelchair -Support for ARTE project in collaboration with Apple Developer Academy -Supervision of Master Thesis consisting in force control for thickness measurement -Contribution to project proposal for deformable object manipulation through visuo-tactile information						
Automatic Control in the Era of Artificial Intelligence	**Seminar**	**1**	**0.2**	**24/03/2025**	**Prof. Bruno Siciliano**	**Y**
Robot Autonomy among Decision-Making Agents	**Seminar**	**1**	**0.2**	**15/04/2025**	**Prof. Fabio Ruggiero**	**Y**
Driving Innovation: Inside KUKA's Research and Development Landscape	**Seminar**	**1**	**0.2**	**16/04/2025**	**Prof. Bruno Siciliano**	**Y**
-Continuation of designing a control framework for humanoid robot to push a wheelchair -Contribution in	**Research**		**9**	**01.03.2025 – 30.04.2025**		

designing Mixed Reality User-friendly Interface for Robot Teleoperation for ARTE project in collaboration with Apple Developer Academy -Experimental activity: Testing and evaluation of Mixed Reality User friendly Interface for Robot Teleoperation -Submission of "A Mixed Reality User-friendly Interface for Robot Teleoperation" paper at International Conference on Social Robotics -Experimental activity: testing and improving compliant non-prehensile pushing manipulation						
"Teoria dei sistemi" (Dynamic systems theory): -Introduction to MATLAB -MATLAB exercise	**Tutorship**	**2**	**0.4**	**01/03/2025 – 30/04/2025**	**Prof. Fabio Ruggiero**	
Human Skill Transfer for	**Seminar**	**1**	**0.2**	**17/06/2025**	**Prof. Bruno**	**Y**

Autonomous and Collaborative Robotics					**Siciliano**	
Robotic Manipulation @Vanvitelli Robotics Lab: A bird's eye view on the last 5 years	**Seminar**	**2**	**0.4**	**18/06/2025**	**Dr. Mario Selvaggio**	**Y**
-Experimental activity: experiments for "Compliant Non-prehensile Pushing Manipulation" completed. -Revised version of "Compliant Non-prehensile Pushing Manipulation" completed and resubmission for possible publication in the IEEE Transactions on Robotics (T-RO). -Paper "A Mixed Reality User-friendly Interface for Robot Teleoperation" accepted at International Conference on Social Robotics (ICSR) and submission of camera-ready version. -Experimental activity: support for Multi-task Reinforcement	**Research**		**9.2**	**01.05.2025 – 30.06.2025**		

Learning for Non-Prehensile Manipulation						
Teoria dei sistemi" (Dynamic systems theory): -MATLAB exercise Field and service robotics: -Support in homeworks correction	**Tutorship**		**0.2**	**01.05.2025 – 30.06.2025**	**Prof. Fabio Ruggiero**	
-Implementation of control framework for humanoid robot to push a wheelchair continued, adding admittance control for the arms. -Experimental activity: demo for humanoid robot to push a wheelchair completed. -Revisions for RAL and T-MECH. -Started state-of-the-art study of reinforcement learning	**Research**		**10**	**01.07.2025 – 31.08.2025**		
-Paper "A Mixed Reality User-friendly Interface for Robot Teleoperation" presented by co-authors at International Conference of	**Research**		**10**	**01.09.2025 – 31.10.2025**		

Social Robotics (ICSR) -Poster "Compliant Non-Prehensile Pushing Manipulation" presented by co-authors at Italian conference of Robotics and Intelligent Machines (I-RIM 3D) -State-of-the-art study of reinforcement learning -Learning of the usage of Isaac Lab and environment setup for robotic manipulation tasks -Training completed for non-prehensile pushing manipulation -Training completed for whole-body multi-contact pushing manipulation						

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**0**	**0**	**10**	**0**	**10**
Bimonth 2	**5**	**0**	**5**	**0**	**10**
Bimonth 3	**0**	**0.6**	**9**	**0.4**	**10**
Bimonth 4	**0**	**0.6**	**9.2**	**0.2**	**10**
Bimonth 5	**0**	**0**	**10**	**0**	**10**

Bimonth 6	**0**	**0**	**10**	**0**	**10**
Total	**5**	**1.2**	**53.2**	**0.6**	**60**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

Topic

The research activity conducted during the current year focuses on robotic manipulation, which have potential applications in service robotics scenarios. Within this context, four different main topics have been investigated:

1. **Pushing a wheelchair with a humanoid robot**;
2. **Robotics teleoperation through a mixed reality user-friendly interface**;
3. **Compliant non-prehensile pushing manipulation**;
4. **Whole-body multi-contact pushing manipulation**.

At present, dexterous manipulation techniques are still not fully mature for deployment in real-world service robotics environments. The topics addressed in this research year aim to push the boundaries of the current state of the art and take a significant step toward possible applicability in service robotics scenarios.

Methodology

1. **Pushing a wheelchair with a humanoid robot**. To push a wheelchair with a humanoid robot, the idea is to exploit the built-in robot walk and to work with the upper limb joints to better perform the task. An admittance control is implemented for the arms and used contextually to the robot pushing execution task. The goal for a future development is to regulate the force while optimizing upper limb configuration to improve stability
2. **Robotics teleoperation through a mixed reality user-friendly interface**. To enable untrained users to effectively operate a robot, an interactive application leveraging SwiftUI, RealityKit, and ARKit, is developed and deployed it on an extended reality (XR) headset. The application enables users to control a robot by moving a virtual sphere that serves as a dynamic target. Using RealityKit's support for natural hand and eye gestures, users guide the robot through easy and subtle motions, eliminating the need for con trollers or exaggerated gestures. The framework is divided into two separate parts, the XR headset application and the robot interface, communicating over Local Area Network (LAN) via a socket through standard TCP/IP protocol. The headset acts as the client, sending a JSON-formatted message to the server on which a robot interface is running.
3. **Compliant non-prehensile pushing manipulation**. Most of this work has been already developed during the first year. To ensure safe robotic pushing manipulation operations in human populated environments, the robot must comply with external physical interactions and exhibit a passive behaviour. To achieve this, we extend a state-of-the-art model to realize a desired pushing force while varying the contact point using an impedance-controlled robot. Control is implemented through optimal modulation of the robot's position and velocity set-point. However, external forces can cause trajectory tracking errors, prompting the pushing controller to compensate by increasing the pushing force. To address this issue, we integrate an energy tank passivity-based control

framework to modulate the velocity set-point in a way that ensures passivity, preventing uncontrolled energy buildup in the system.

4. **Whole-body multi-contact pushing manipulation**. Performing whole body multi-contact pushing manipulation is very complex with model-based approaches since choosing the optimal contact point location is not trivial. Model-based planners are too slow to be used in an online feedback control to solve this task. Hence, the adopted approach is based on Reinforcement Learning, which, in favorable conditions like initial configuration and elementary object shape, can easily solve the problem. The goal for the future development is to understand the limits of a traditional Reinforcement Learning approach for this task and understand possible advantages including information deriving from the model-based planner.

Results

1. **Pushing a wheelchair with a humanoid robot**. The robot showed to be able to push a wheelchair with people of highly different weights sitting on it along a linear trajectory.
2. **Robotics teleoperation through a mixed reality user-friendly interface**. The framework has been statistically evaluated over a heterogeneous user sample who was asked to complete three different manipulation tasks. The evaluation has been done using the subjective standard measures NASA Task Load Index (TLX) and System Usability Scale (SUS), as well as a custom designed questionnaire. Results showed that errors and execution times were within acceptable limits, confirming reliable and efficient system performance. User feedback showed low workload (NASA-TLX) and high usability (SUS). The software was easy to use, with tasks seen as manageable. Users were highly satisfied with position control, though orientation control—managed via a sensitive slider—received slightly lower ratings. Overall feedback was very positive, highlighting comfort and ease of use.
3. **Compliant non-prehensile pushing manipulation**. The framework had been already validated in simulation using a 7-DOF KUKA LBR iiwa 7 as well as on the real system ABB Mobile Yumi in the first-year work, to show the passive interaction. During the second year, a supplementary experimental campaign has been conducted on KUKA LBR iiwa 7, to show trajectory tracking capabilities under uncertainties and at higher speed. On iiwa, tests under varying friction, mass, path, and velocity showed performance degradation mainly at higher rotational friction, lower mass, curved paths, or higher speed. Overall, mean errors (0.0165 m, 0.1003 rad) remained comparable to state-of-the-art methods.
4. **Whole-body multi-contact pushing manipulation**. The learned policy has been tested in simulation in favorable conditions of suitable initial configuration and cylindrical object shape. The results showed an average success rate between 85% and 90%, computed as succeeded episodes over completed episodes.

4. Research products:

Scientific paper: **Compliant Non-Prehensile Pushing Manipulation.**
Authors: **F. Cufino, M. Selvaggio, F. Amadio, F. Ruggiero.**
Journal: **IEEE Transactions on Robotics.**
Current state: **decision pending.**

Scientific paper: **A Mixed Reality User-friendly Interface for Robot Teleoperation.**

Authors: **M. Chemerys, M. Novoselov, S. D. M. Santos, R. Aliotta, F. Cufino, and F. Ruggiero**
Conference: **International Conference of Social Robotics (ICSR) (2025).**

5. Conferences and seminars attended

6. Activity abroad

Whole body multi-contact pushing manipulation, in the period 01.09.2025 – 31.10.2025 at The University of Edinburgh, under the supervision of Prof. Sethu Vijayakumar, with the Statistical Learning and Motor Control group (SLMC).

7. Tutorship

"Teoria dei sistemi" (Dynamic systems theory), 4 hours:

- Introduction to MATLAB.
- Exercises with MATLAB.

"Field and Service Robotics":

- Support in Homework correction