Università degli Studi di Napoli Federico II

PhD program in

Information Technology and Electrical Engineering

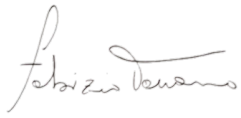
PhD Student: Fabrizio Tavano

Cycle: XXXV

Training and Research Activities Report

Academic year: 2020-21 - PhD Year: Second

student signature



Tutor: prof. Vincenzo Lippiello *tutor signature*

Co-Tutor: dott. Riccardo Caccavale

Date: October 29, 2021

Training and Research Activities Report

PhD program in Information Technology and Electrical Engineering

PhD student: **Cycle: XXXV**

1. Information:

- **PhD student:Fabrizio Tavano** **PhD Cycle:XXXV**
- **DR number: DR993890**
- **Date of birth:29081981**
- **Master Science degree: Electronic Engineering University: Second University of Naples**
- **Scholarship type: no scholarship**
- **Tutor: prof. Vincenzo Lippiello**
- **Co-tutor: dott. Riccardo Caccavale**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Telemedicina in Italia: casi di successo	Seminar	3	0.6	17 novembre 2020	prof. ing. Giovanni D'Addio, DIETI, Corso di Dispositivi per la Telemedicina	Y
GDPR basics for computer scientists, lecturer: Dr. Rigo Wenning,	Seminar	1,5	0.3	10 December 2020	Prof. Piero Bonatti,Prof.ssa Anna Corazza	Y
Exploiting medical imaging in the era of big data; lecturer: Dr Marco Aiello,	Seminar	2	0.4	10 December 2020	Prof. Piero Bonatti,Prof.ssa Anna Corazza	Y
#andràtuttobene: Images, Texts, Emojis & Geodata in a Sentiment Analysis Pipeline; lecturer: Prof. Serena Pelosi	Seminar	1,5	0.3	25 November 2020	Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato	Y
At the Nexus of Big Data, Machine Intelligence,	Seminar	1	0.2	2 December 2020	Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato	Y

and Human Cognition						
Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics; lecturer: Prof. Giuseppe Manco	**Seminar**	**1**	**0.2**	**9 December 2020**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Data Driven Transformation in WINDTRE through Managers voice; lecturer: Marcello Savarese	**Seminar**	**2**	**0.4**	**16 December 2020**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
From Photometric redshifts to improved weather forecasts: an interdisciplinary view on machine learning; lecturer: Prof. Kai Polsterer, Heidelberg Institute for Theoretical Studies HITS	**Seminar**	**1**	**0.2**	**13 January 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
The era of Industry 4.0: new frontiers in business model innovation; Lecturer:Marco Balzano – university Ca' Foscari in Venice	**Seminar**	**1**	**0.2**	**3 February 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Machine Learning;causality lost in translation; lecturer:Edwin A. Valentijn – Rijksuniversiteit Groningen;	**Seminar**	**1.5**	**0.3**	**10 February 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Approaches to Graph Machine Learning;Lecturer: Miroslav Cepek– Oracle Labs	**Seminar**	**1.5**	**0.3**	**17 February 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**

Convegno:"Droni, fare Sistema per un maggiore sviluppo"	**Seminar**	**3**	**0.6**	**16 February 2021**	**lecturers: Prof.Alessandro Perego,Prof.Giuseppe Sala, dott.ssa Paola Olivares,dott. Vincenzo Butticè, dott. Stefano Giovannini, dott. Marco Lovera, dott. Giuseppe Gori, dott. Fabio Bosatelli,dott. Matteo Sinopoli, dott. Cristina Rossi Lamastra,dott. Alessandro Renzo, dott. Laura Piantanida, dott. Davide Invernizzi,dott. Paola Castagna,dott. Evila Piva,Marco Lovera, dott. Giovanni Battista Gallus,dott. Valentino Sevino,dott. Marco Pironti, dott. Silvia Pantanella, dott. Carmela Tripaldi, dott. Andrea Mezzetti; organizer: Osservatori.net digital innovation, Politecnico di Milano,Organizer: Osservatori.net digital innovation, Politecnico di Milano, dipartimento di scienze e tecnologie**	**Y**

					aerospaziali.aerospace system and control laboratory	
“Il Risanamento napoletano: cura per la città 'malata”, “The History of Pandemics to Support Public Health Preparedness and Epidemiological Modelling for COVID-19”;	**Seminar**	**2**	**0.4**	**24 February 2021**	**dipartimento di Architettura, Dipartimento di Sanità Pubblica**	**Y**
Visual Interaction and Communication in Data Science	**Seminar**	**2**	**0.4**	**03 March 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Big data and computational linguistics	**Seminar**	**2**	**0.4**	**10 March 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
The coming revolution of Data driven Discovery (a fourth Methodological Paradigm of Science), lecturer: Prof. Longo	**Seminar**	**1.5**	**0.3**	**25 March 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Distributional Semantics Methods: How Linguistic features can improve the semantic representation; lecturer: Alessandro Maisto	**Seminar**	**1.5**	**0.3**	**28 April 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Artificial intelligence and 5G combined with holographic technology: a new perspective for remote healt monitoring; lecturer: Dr.Pietro Ferraro, Dr. Pasquale Memmolo	**Seminar**	**2**	**0.4**	**27 April 2021**	**Prof. Antonia Maria Tulino;**	**Y**

Convegno:"Scienza e cultura della pace, in ricordo di Pietro Greco"	**Seminar**	**4**	**0.8**	**13 April 2021**	**Comitato organizzatore del gruppo RUniPace UNINA: Maria Carmela Agodi, Francesco Giannino, Marco Musella, Stefano Oliverio, Ilenia Picardi, Simon Pietro Romano, Maura Striano, Guglielmo Tamburrini Patrocinio RUniPace; USPID;**	**Y**
Introduzione del 5G nel sistema ferroviario	**Seminar**	**2.5**	**0.5**	**15 March 2021**	**Collegio Ingegneri Ferroviari Italiani CIFI**	**Y**
Dalla manutenzione ciclica alla manutenzione predittiva: la diagnostica mobile della infrastruttura di Rete Ferroviaria Italiana,	**Seminar**	**2.5**	**0.5**	**date 4 March 2021**	**Collegio Ingegneri Ferroviari Italiani CIFI**	**Y**
Optimized Graph Representations for Right-Wing Reddit Community Using Graph Neural Networks; lecturer: Mr Mohammad Diaoulé Diallo, University of Bielefeld	**Seminar**	**1**	**0.2**	**30 April 2021**	**Prof. Silvia Rossi, DIETI, UNINA Priscalab**	**Y**
Introduction to Legged robots and examples of IIT's Dynamic Legged Systems Lab	**Seminar**	**2**	**0.4**	**26/May/2021**	**Lecturer: Dr. Claudio Semini, Dr. Michele Focchi, Organizer:Prof. Fabio Ruggiero**	**Y**
Introduction to underwater robotics	**Seminar**	**2**	**0.4**	**18/May/2021**	**lecturer: Dr. Claudio Semini, Prof. Gianluca Antonelli Organize:Prof. Fabio Ruggiero**	**Y**

3EM Group: attività nell'ambito dei sistemi di progettazione industriale	**Seminar**	**1**	**0.2**	**19 May, 2021**	**lecturer: 3MGroup, Organizer: Prof. De Tommasi**	**Y**
End-to-End Optimization of Augmented Experience Services over Cloud-Integrated 5G Networks	**Seminar**	**4**	**0.8**	**15-16/06/2021**	**lecturer: Pr. Jaime Llorca; organizer: Prof.ssa Antonia Maria Tulino;**	**Y**
Sadas Engine, an innovative DBMS for the DATA WAREHOUSE, great PERFORMANCE in the VLDB environment	**Seminar**	**2**	**0.4**	**23 June 2021**	**lecturer: Eng. Luca De Rosa, technical manager SADAS organizer: DIETI,PICARIELLO LECTURES ON DATA SCIENCE, Prof. Longo, Prof. Amato**	**Y**
SMCV- Sistemi di misura dei Carichi Verticali	**Seminar**	**3**	**0.6**	**22 june 2021**	**,Lecturer: Prof. Malavasi, università di Roma La Sapienza organizer: Collegio Ingegneri Ferroviari Italiani CIFI**	**Y**
Il rumore ferroviario dalle cause del fenomeno agli interventi di mitigazione	**Seminar**	**2.5**	**0.5**	**26 March 2021**	**Collegio Ingegneri Ferroviari Italiani CIFI**	**Y**
Sensoria Healt; lecturer: Stefano Rossotti	**Seminar**	**1**	**0.2**	**17 March 2021**	**Picariello lectures on data science SCIENCE, Prof. Longo, Prof. Amato**	**Y**
Recovery Lab: Transizione digitale e sviluppo delle reti di telecomunicazione	**Seminar**	**1**	**0.2**	**11st october 2021**	**lecturer: Prof. Michele Polo, Eni Chair in Energy Markets at Università Bocconi di Milano organizer: Il Dipartimento di Scienze Economiche e Statistiche dell'Università di**	**Y**

					Napoli Federico II, Recovery Lab	
Qiskit: state of the art and tools for Quantum Computers from IBM,	**Seminar**	**2**	**0.4**	**15th October 2021**	**lecturer: Dr. Federico Accetta, IBM Italia, organizer: Prof.ssa A. S. Cacciapuoti (DIETI, UniNA),**	**Y**
Second Quantum Revolution: innovation trends and expected industrial impacts	**Seminar**	**2**	**0.4**	**22nd October 2021**	**lecturer: Dr. Antonio Manzalini, organizer: Prof.ssa A. S. Cacciapuoti (DIETI, UniNA)**	**Y**
SIDRA 2021 PhD Summer School (30 hours), titles: "Game Theory and Network Systems", "Modeling and Control of Soft Robotics"	**PhD Summer School**	**30**	**3**	**12-17 July 2021**	**University of Bologna**	**Y**
Intelligent robotics	**MSc course**		**6**	**Second semester**	**Università di Napoli Federico II; Prof. Alberto Finzi**	**Y**
Image and Video Processing for Autonomus Driving	**MSc course**		**6**	**Second semester**	**Università di Napoli Federico II; Prof. Luisa Verdoliva**	**Y**
Image Processing for Computer Vision	**MSc course**		**9**	**Second semester**	**Università di Napoli Federico II; Prof. Giuseppe Scarpa**	**Y**
Neural Networks and Deep Learning	**MSc course**		**6**	**Second semester**	**Università di Napoli Federico II;Prof. Giuseppe Prevete**	**Y**
Text Mining	**MSc course**		**6**	**Second semester**	**Università di Napoli Federico II; Prof. Flora Amato**	**Y**
Natural language Processing	**MSc course**		**6**	**Second semester**	**Università di Napoli Federico II:Prof. Francesco Cutugno**	**Y**
Statistical Learning	**MSc course**		**6**	**First semester**	**Università di Napoli Federico II;Prof. Anna Corazza**	**Y**
Human-Robot Interaction	**MSc course**		**6**	**First semester**	**Università di Napoli Federico II;Prof. Silvia Rossi**	**Y**
Fondamenti di Robotica	**MSc course**		**9**	**First semester**	**Università di Napoli Federico II:Prof. Bruno Siciliano**	**Y**

Data Management	**MSc course**		**6**	**First semester**	**Università di Napoli Federico II; Prof. Flora Amato**	**Y**
Ad hoc course, title: deep learning and computer vision for autonomous systems: focus on drone vision, imaging surveillance and cinematography	**Ad hoc course**	**17**	**1,5**	**18-19 November 2020**	**Prof. Ioannis Pitas, Aristotle University of Thessaloniki, CELLL Center for education and lifelong learning**	**Y**
In this study we propose the use of a group of robot-sanitizers for use in current railway stations. We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, The team of robots will be driven in an appropriate manner to sanitize the environment in continuous manner during the day. The robots will be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays. In particular, I have studied the	**Research**		**10**	**1.11.2021 - 31.12.2021**	**Prof. Lippiello**	**Y**

centralized strategy of cooperation that will be implemented and optimized thanks to deep Q-learning methods.						
In this study we propose the use of a group of robot-sanitizers for use in current railway stations. We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, The team of robots will be driven in an appropriate manner to sanitize the environment in continuous manner during the day. The robots will be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays. In particular, I have studied a decentralized strategy of cooperation	**Research**		**10**	**1.01.2021 – 28.02.2021**	**Prof. Lippiello**	**Y**

implemented with deep Q-learning method approach. I have developed a multithreading decentralized strategy of cooperation in python language, using deep Q-learning methods thanks to the libraries Keras and TensorFlow						
Development of an multirobot Deep Q-Learning approach to sanitize the railway stations from Covid-19 disease. Every agent has its own neural network, so the robot make its own decision on the direction to go to sanitize. We have considered and reproduced in our simulation the environment of Italian railway station Roma Termini. In these months I have developed also a program of test for the testing of the solution, to verify the efficiency of the solution.	**Research**		**10**	**1.03.2021 – 30.04.2021**	**Prof. Lippiello**	**Y**
I have actively participated to the correction of on-line exercitations and and home-works for the training of the students for the following MSc	**Tutorship**	**25**	**1**	**1.03.2021 – 30.04.2021**	**Prof. Lippiello**	**Y**

courses:Module: Teoria dei stistemi, duration 15 hours, Professor: Prof. Lippiello Module: Robotics Lab: duration 10 h, Professor: Prof. Lippiello						
In this study we propose the use of a group of robot-sanitizers for use in current railway stations. We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, The team of robots will be driven in an appropriate manner to sanitize the environment in continuous manner during the day. The robots will be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays. In particular, I have studied in these two	**Research**		**8**	**1.05.2021 – 30.06.2021**	**Prof. Lippiello**	**Y**

months an approach based on A2C reinforcement learning technics, and I have compared it with the buffer replay technics.						
I have actively participated to the correction of on-line exercitations and and home-works for the training of the students for the following MSc courses:Module: Teoria dei stistemi, duration 5 hours, Professor: Prof. Lippiello Module: Robotics Lab: duration 10 h, Professor: Prof. Lippiello	**Tutorship**	**15**	**0.6**	**1.05.2021 – 30.06.2021**	**Prof. Lippiello**	**Y**
In this study we propose the use of a group of robot-sanitizers for use in current railway stations. We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, The team of robots will be driven in an appropriate manner to sanitize the environment in continuous manner during the day. The robots will	**Research**		**8**	**1.07.2021 – 31.08.2021**	**Prof. Lippiello**	

be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays. In particular, I have studied and developed in these two months an approach based on Double Deep Q-Network and Dueling Deep Q Network reinforcement learning technique, and I have compared it with the DQN buffer replay technique and A2C technique.						
In this study we propose the use of a group of robot-sanitizers for use in current railway stations. We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, The team of robots will be driven in an appropriate manner to sanitize	**Research**		**9**	**01.09.2021 – 31.10.2021**	**Prof. Lippiello**	

the environment in continuous manner during the day. The robots will be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays. in particular, I have extracted data about aggregation of people from heatmaps images of the station Roma Termini, Italy, available by Meraki Cisco System web Portal. I have analysed data to extract recurrences and periodicity of behaviour of people represented in the heatmap, by computer vision algorithms, comparing different heatmaps realized in different days of weeks and different hours. I Have also extracted information from a Json file where there are real measurements about one day, that I will						

utilize to test our solutions. I am developing an algorithm of model predictive control for the coordination of the team of robots.						

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	22.5	2.4	10	0	34,9
Bimonth 2	6	2	10	0	18
Bimonth 3	0	4.5	10	1 (25 hours)	15,5
Bimonth 4	12	2.8	8	0.6 (15 hours)	23,4
Bimonth 5	30	0	8	0	38
Bimonth 6	0	1	9	0	10
Total	70,5	12,7	55	1,6	139,8
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

In recent years, the spreading of diseases such as the Covid-19 has emphasized the problem of sanitizing large and crowded public environments like railway stations. In the present work,we have developed and tested the solution for the sanitizing by the deep q learning technique in a real case of study of interest for Italian railway infrastructure manager RFI s.p.a., in areal environment offered by the most important italian railway station of the capital, Rome Termini. The framework relies on anonymous information from existing WiFi networks to localize passengers inside the station and to develop a map of possible risky areas to be sanitized. Starting from this map, a swarm of cleaning robots, each one endowed with a robot-specific convolutional neural network, learns how to on-line cooperate inside the station in order to maximize the sanitized area depending on the presence of the passengers. In this study we have adopted a decentralized approach, where every robot makes its own decision to solve its task. In this work, we proposed a scalable Deep Q-Learning approach to multi-robot sanitization of railway stations. The proposed framework exploits real-time knowledge about the distribution of people in the environment, provided by the preexisting WiFi infrastructure, to generate a priority map of areas to be sanitized. Such map is exploited by a set of robots, each endowed with a convolutional neural network, to learn how to optimize the sanitization processes. We tested the overall framework in a realistic simulated scenario, which was designed in cooperation with the italian railway infrastructure manager (RFI S.p.A.), considering the largest and more populated Italian railway station (Roma Termini) as a case study. The collected results show that the proposed framework is suitable for the sanitation of large indoor environments, such as railway stations. We also discussed the scalability of the proposed method with respect to the number of involved robots and to the density of people in the station.

We have tested the solution for the sanitizing by the Deep Q-learning technique in a real case of study of interest for Italian railway infrastructure manager RFI s.p.a., in a real environment offered by the most important italian railway station of the capital, Rome Termini. We have verified the behavior of teams of robots with different number of members to verify how to vary the improvement, comparing different solutions. We tested also the behavior of the solution in presence of several number of clusters of passengers that move inside the station.

In this study we have adopted a decentralized approach, where every robot makes its own decision to solve its task. From our work, it emerges that every robot, after the training of its own convolutional neural network, decides to move in coordination and collaboration with the other members of its team, in order to maximize the reward based on the quantity "dirty" that is removed from the heatmap. A robot in our experiment, doesn't know the position of the other robots that collaborate with it but their paths.

4. Research products

The following article is submitted:

Riccardo Caccavale, Vincenzo Calà, Mirko Ermini, Alberto Finzi, Vincenzo Lippiello and Fabrizio Tavano: title: “A Multi-robot Deep Q-Learning Framework for Priority-based Sanitization of Railway Stations”; AIRO 2021: 8th Italian Workshop on Artificial Intelligence and Robotics of the 20th International Conference of the Italian Association for Artificial Intelligence (AI*IA 2021),online, December 1st-3rd, 2021

5. Conferences and seminars attended

In the following table, the attended courses are listed:

Course Attended	Type	Organizer
Ad hoc course, title: deep learning and computer vision for autonomous systems: focus on drone vision, imaging surveillance and cinematography	Ad hoc course	Prof. Ioannis Pitas, Aristotle University of Thessaloniki, CELLL Center for education and lifelong learning
SIDRA 2021 PhD Summer School (30 hours), titles: “Game Theory and Network Systems”, “Modeling and Control of Soft Robotics”	PhD Summer School	University of Bologna

6. Periods abroad and/or in international research institutions

Period: 15.09.2021 - 15.12.2021

Location: Université Libre de Bruxelles, Département : Service d’Automatique et d’Analyse des Systèmes; Chef de service :Prof. Michel Kinnaert; Collaboration in the project of research with: Prof. Emanuele Garone

topic of research:

This research activity proposes the use of a group of robot-sanitizers for use in current railway stations.

We start with the hypothesis that the these robots will be equipped with electric motors that allow movement on the wheels, they will work with autonomy, During the present study, it will be developed a specific allocation and patrolling task algorithm to optimize the coordination and strategic movement of the robot team for an effective and fast fulfillment of the common objective, to sanitize and keep the environment, sanitized over the day.
In particular, we suppose that a server system will be able to recognize the aggregations of passengers thanks to the localization of the position of smartphones thanks to the trilateration technique applied to WiFi signal between more than one access point in the station.
The team of robots will be driven in an appropriate manner to sanitize the environment in continuous manner during the day. The robots will be able to cooperate, choosing effective paths, distinguishing obstacles from people, and applying different disinfection methods, such as the diffusion of bactericidal chemicals, or lighting up the surfaces by UV rays.
A centralized strategy of cooperation will be selected and optimized thanks also to a Model Predictive Control method. In this manner, it will be possible to do a comparison between the results obtained by the adoption of model-based methods than model-free reinforcement learning algorithm methods.
We extract data about aggregation of people from heatmaps images of the station Roma Termini, Italy, available by Meraki Cisco System web Portal. We study the datas to extract recurrences and periodicity of behaviour of people represented in the heatmap, by computer vision algorithms, comparing different heatmaps realized in different days of weeks and different hours. We extract information from a Json file where there are real measurements about one day, that I will utilize to test our solutions.

7. Tutorship

In the period between 1.03.2021- 30.06.2021, I have actively participated to the correction of on-line exercitations and and home-works for the training of the students for the following MSc courses:

- Robotic Labs: 20 hours
- Theory of Systems : 20 hours

For a total of 1.6 credits.

8. Plan for year three

As future research activities, we plan to extend our pilot study by testing the proposed framework in a more realistic scenario, considering more complex robotic models and daily recorded data about people distribution in the station. Furthermore, multi-agent strategies including teams of heterogeneous robots with different cleaning capabilities are currently under investigation.

The centralized strategy of cooperation will be chosen and optimized thanks to Model predictive control method. In this manner, it will be possible to do a comparison between the results obtained by the adoption of model-based methods than model-free reinforcement learning algorithm methods.

It is under investigation a study in which there will be a comparison between several model-free reinforcement learning algorithms. In particular, I have developed for the same context and target, the following approaches:

1. Buffer replay DQN
2. A2C DQN technic
3. DDQN technic
4. Duel-DQN technic
5. Duel-DDQN technic

It will be compared also the decentralized approach of a Buffer replay DQN, where every robot has its own neural network, with the centralized one, with one network that select the actions to do for every robot.

The thesis will have the title: A Multi-robot Framework for Priority-based Sanitization of Railway Stations.
In the thesis we propose the multi-robot approaches to sanitize railway stations based on a distributed Deep Q-Learning technique and Model Based technics as Model Predictive Control methods.
The framework relies on anonymous information from existing WiFi networks to localize passengers inside the station and to develop a map of possible risky areas to be sanitized. Starting from this map, a swarm of cleaning robots learns how to on-line cooperate inside the station in order to maximize the sanitized area depending on the presence of the passengers.

The main topics are also described in the paragraph 3 (Research activity), 6 (Periods abroad and/or in international research institutions) and 8 (Plan for year three) of the present document.
In synthesis the topics will be:

- A Priority-based decentralized multi-robot approach to sanitize railway stations based on a distributed Deep Q-Learning technique, Buffer Replay Deep Q-Network; it represents a novelty where prioritization issues are hardly considered in actual literature.
- We have tested the solution for the sanitizing by the Deep Q-learning technique in a real case of study of interest for Italian railway infrastructure manager RFI s.p.a., in a real environment offered by the most important italian railway station of the capital, Rome Termini. We have verified the behavior of teams of robots with different number of members to verify how to vary the improvement, comparing different solutions. We tested also the behavior of the solution in presence of several number of clusters of passengers that move inside the station.
- We will study a comparison between several model-free reinforcement learning algorithms.
- It will be compared also the decentralized approach of a Buffer replay DQN, where every robot has its own neural network, with the centralized one, with one network that select the actions to do for every robot.
- It will be studied the strategies of cooperation of treams of robots based on a Model Predictive Control method.
- It will be done the comparison between the results obtained by the adoption of model-based methods with the model-free reinforcement learning methods.

In the next year it is planned the continuation of the activities of tutorship for the following MSc courses:

- Robotic Labs
- Theory of Systems

For the third year, it is planned to follow the courses in table below:

Course	Organizer
MSc course, title: Control System Design	Prof. Garone (ULB, Brussels, Belgium)
MSc course, title: Optimization-based Control	Prof. Garone (ULB, Brussels, Belgium)
SIDRA 2022 PhD Summer School	University of Bologna
MSc course, title: Data Mining	Prof. Longo (Univerisity of Naples Federico II)