Andrea Gasparri

Professor

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I Education

2008	**Ph.D.** in Computer Science and Automation, Faculty of Engineering / Department of Computer Science and Automation, Roma Tre University, Italy.
2004	**MSc** *summa cum laude* in Computer Science Faculty of Engineering / Department of Computer Science and Automation, Roma Tre University, Italy.

II Position

2023–Present	**Professor**, Department of Civil, Computer Science and Aeronautical Technologies Engineering (Department of Engineering until 31/12/2022), Roma Tre University, Italy
2016–2023	**Associate Professor**, Department of Civil, Computer Science and Aeronautical Technologies Engineering (Department of Engineering until 31/12/2022), Roma Tre University, Italy
2014–2016	**Assistant Professor (Tenured)**, Department of Engineering, Roma Tre University, Italy
2011–2014	**Assistant Professor (Tenure track)**, Faculty of Engineering / Department of Computer Science and Automation, Roma Tre University, Italy
May 2013 – June 2013	**Visiting Professor**, Ming Hsieh Institute, Department of Electrical Engineering, University of Southern, California, California – USA
April 2012 – May 2012	**Visiting Professor**, Faculté des Sciences appliquées, Ecole Polytechnique de Bruxelles, Université Libre de Bruxelles, Bruxelles – Belgium
2008–2011	**Postdoctoral Scholar**, Faculty of Engineering / Department of Computer Science and Automation, Roma Tre University, Italy
July 2008 – Sept. 2008	**Visiting Scholar**, CCNY Robotics Lab, Electrical Engineering Department, The City College of New York (CCNY), New York – USA
April 2007 – Sept. 2007	**Visiting Scholar**, ANRG, Department of Electrical Engineering, University of Southern California, California – USA

III Awards

2019 **Young Author Award** (as co-supervisor) for the 6th IFAC Conference on Sensing, Control and Automation Technologies for Agriculture (AGRICONTROL 2019) for the paper N. Bono Rosselló, R. F. Carpio, A. Gasparri, E. Garone, “A novel Observer-based Architecture for Water Management in Large-Scale (Hazelnut) Orchards”. Young Author: Mr. Nicolás Bono Rosselló.

2018 **IEEE RAS Italian Chapter "Fabrizio Flacco" Young Author Best Paper Award 2018** (as co-author / first author) for the paper A. Gasparri, L. Sabattini, G. Ulivi. Bounded Control Law for Global Connectivity Maintenance in Cooperative Multirobot Systems. Transactions on Robotics, IEEE, 33(3):700 – 717, 2017. Young Author: Lorenzo Sabattini

2018 **Italian National Scientific Qualification** for **Full Professor**, (Research Area: Automation, National Code: 09/G1)

2017 **Best Multi-Robot Systems Paper Award Finalist** for the 2017 IEEE International Conference on Robotics and Automation (IEEE ICRA 2017) in Singapore for the paper R. K. Williams, A. Gasparri and G. Ulivi, “Decentralized Matroid Optimization for Topology Constraints in Multi-Robot Allocation Problems”

2014 **Italian National Scientific Qualification** for **Associate Professor**, (Research Area: Automation, National Code: 09/G1)

2010–2014 **Research Grant FIRB “Futuro in Ricerca 2008”**, project “Networked Collaborative Team of Autonomous Robots (NECTAR)”, Italian Ministry of Research and Education (MIUR). Acceptance Rate 2.8%

IV Fellowships and Visiting (Official Teaching and Research Posts)

2017 **Visiting Professor** at Virginia Tech’s Department of Electrical and Computer Engineering. As part of the visit, Prof. A. Gasparri carried out research in collaboration with Prof. Ryan K. Williams and his research team. From 19-07-2017 to 07-08-2017

2013 **Distinguished Visiting Fellow Program** from the Ming Hsieh Institute in the Ming Hsieh Department of the Department of Electrical Engineering of the USC Viterbi School of Engineering in 2013. Prof. A. Gasparri’s candidacy for the Visitor Program was proposed by Prof Gaurav Sukhatme and Prof. Bhaskar Krishnamachari. From 21-05-2013 to 30-06-2013.

2012 **Teaching Fellowship** at the Université Libre de Bruxelles (ULB) within the Lifelong Learning Program (LLP) -Erasmus, Individual Teaching Program for Teaching Staff Mobility, for 9 hours of teaching for Master and Doctorate students on “Formation Control and Data Fusion problems for Multi-Robot Systems”. From 10-04-2012 to 03-05-2012.

2008 **Visiting Researcher** at the Department of Electrical Engineering of the City College of New York (CCNY), in New York City. As part of the visit, Prof. A. Gasparri carried out research in collaboration with Prof. John (Jizhong) Xiao and Prof. Peter Brass. From 21-07-2008 to 07-09-2008.

V Affiliations (Work at Academies)

2018–Present **Collaborateur Scientifique (Affiliated Researcher)** to the Service d’Automatique et d’Analyse de Systemes (SAAS) of the Université Libre de Bruxelles (ULB). Among the various activities related to the appointment of Prof. A. Gasparri at SAAS there is the co-supervision of PhD student Nicolás Bono Rosselló.

VI Technology Transfer

03/07/2019	**Patent:** Italian Patent n. 102018000006385 "Metodo ed architettura di gestione della domanda energetica di tipo multi-agente per la riduzione dei picchi di consumo elettrico di una pluralità di apparecchiature elettriche." Status: Approved.

VII Teaching Activities

A Teaching

2022–Present	**Professor** – Robotics (3 ECTS), Roma Tre University / Italy (Master Degree in "Ingegneria Gestionale e dell'Automazione" – 3 CFU)
2020–Present	**Professor** – Complex robotic systems laboratory (3 ECTS), Roma Tre University / Italy (Master Degree in "Ingegneria Gestionale e dell'Automazione" – 3 CFU)
2020–Present	**Professor** – Dynamics and Control of Complex Systems (9 ECTS), Roma Tre University / Italy (Master Degree in "Ingegneria Gestionale e dell'Automazione" – 9 CFU)
2016–Present	**Professor** – Basis of Automatic Control (6 ECTS), Roma Tre University / Italy (Bachelor Degree in "Ingegneria Elettronica" – 6 CFU)
2011–2020	**Professor** – System and Control Theory (12 ECTS), Roma Tre University / Italy (Master Degree in "Ingegneria Gestionale e dell'Automazione" – 12 CFU)
2008–2011	**Professor** – System and Control Theory (6 ECTS), Roma Tre University / Italy (Master Degree in "Ingegneria Gestionale e dell'Automazione" – 6 CFU)

B Teaching Assistant

2007–2008	**Teaching Assistant** – Automatic Control (6 ECTS), Roma Tre University / Italy

C Institutional Responsibilities

2022–Present	**Vice-Coordinator** of the Computer Science Engineering Teaching Committee, Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University / Italy
2021–Present	**Member** of the Doctoral School Board in National PhD in Artificial Intelligence, Agrifood and Environment, Università degli Studi di Napoli Federico II / Italy
2013–Present	**Member** of the Doctoral School Board in Computer Science and Automation, Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University / Italy
2011–Present	**Member**, Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University / Italy
2011–Present	**Member** of the Computer Science Engineering Teaching Committee, Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University / Italy

VIII Editorship

2021–Present	**Associate Editor** for the IEEE Transactions on Control of Network Systems (IEEE TCNS)
2017–Present	**CEB Associate Editor** for the IEEE Control System Society (IEEE CSS)
2017–2020	**Associate Editor** for the IEEE Transactions on Cybernetics (IEEE TCyb)

IX Research Activities

A Research Group

Prof. A. Gasparri is currently the coordinator of the Networked Multiagent Systems (NEWLINE) Research Group at the Department of Civil, Computer Science and Aeronautical Technologies Engineering at the University of Roma Tre.

The NEWLINE Research Group is a teaching and research laboratory on Robotics and Networked Multiagent Systems with research interests including robotics, sensor networks, networked multi-agent systems and precision agriculture. The NEWLINE Research Group is focused on the development of distributed methodologies for the estimation, control and optimization of collaborative multi-agent systems, and more recently the application of robotic systems for precision agriculture. The staff of the NEWLINE Research Group is also involved in the graduate and undergraduate education programs in Computer Science and Automation Technology and in Electrical Engineering at the University of Roma Tre.

Further information on the NEWLINE Research Group can be found at `https://newline.inf.uniroma3.it`.

B Research Interests

The main research topics of Prof. A. Gasparri are in the fields of:

1. Distributed Coordination in Multi-Agent Systems
2. Distributed Optimization and Decision-Making in Multi-Agent Systems
3. Distributed Estimation in Multi-Agent Systems
4. Robotics and Control Methodologies for Precision Agriculture

B.1 Distributed Coordination in Multi-Agent Systems

Distributed Coordination in Multi-Agent Systems has been a very popular research topic within the Control and Robotics communities over the last few decades. The interest in this research subject is related to the fact that a team of agents, e.g., a fleet of mobile robots, compared to single agents, can usually provide a remarkably higher level of robustness and flexibility, such as in the context of collaborative transportation or monitoring. Notably, what makes this problem particularly challenging is that the agents are subjected to limitations on the available information, which has made graph-based models useful and natural tools for encoding these limitations. In this regard, the research activity of Prof. A. Gasparri has focused on several aspects of the multi-agent coordination problems including topology control, formation control, mission control, and unknown environment exploration.

The development of coordination algorithms for a multi-agent system requires a constant and reliable exchange of information (either through direct communication, for example using a Zigbee transceiver, or through indirect communication, for example through sensory devices) between the various team members. For this reason, a strictly related and particularly relevant research problem is the control of the network topology encoding the interaction between agents. In this context, two different operating scenarios can be considered: i) each robot has a 360-degree field of view (from which it follows a modeling of the topology based on undirected graphs), and ii) each robot has a limited field of view (from which it follows a modeling of the topology based on directed graphs). In the first case, the research activity focused on the development of decentralized (bounded) control laws that can provably preserve the connectivity of the multi-robot system over time by coupling an online estimation of the algebraic connectivity of the team with a connectivity control term that can overcome other control actions in case connectivity is about to get lost ([A11, C55, C56, A25]). The effectiveness of these techniques has been experimentally validated through the use of the SAETTA mobile robot team available at the NEWLINE research group. This research direction has been then generalized in [A26] to address the problem of controlling arbitrary topological constraints through team motion while allowing the network topology of the system to switch arbitrarily, with potential-based mobility being discontinuous with respect to topology changes. Such discontinuities are a reality of spatially interacting systems and can arise from non-ideal communication, proximity-limited inter-robot sensing, heterogeneous robot mobility, unexpected failures, etc. In the second case, the research activity initially focused on the development of distributed algorithms to identify a critical connected structure, e.g., strongly connected subgraph, within the direct graph encoding the network topology ([C29, C36]) in order to develop topology control techniques for robotic networks with limited field of views. Successively, it has been extended in [C68, A37] to address the problem of coordinating the motion of a team of robots with limited fields of view (FOVs), which induces asymmetry in their interactions. In this context, we first proposed a general coordinated motion framework for multi-robot systems with triangular FOVs capable of guaranteeing stability for general potential-based motion with asymmetric interactions, which captures various coordinated objectives, including the ability to actively control topology over time. In deriving this framework, we illustrated that asymmetry in multi-robot interactions can lead to degenerate configurations for which a fully decentralized controller may be insufficient to achieve coordination. Thus, we introduced a switching control mechanism that achieves adaptive decentralization, enabling collaborative behaviors that seek the support of a centralized planner for situations that are inherently unstable (degenerate). To demonstrate the generality of our framework we provided a case study involving varying team objectives, such as topology control, that the robots can achieve with limited FOVs while remaining stable. The correctness of the proposed framework has been validated both through numerical and experimental validation by resorting to the team of four DJI M100 unmanned aerial vehicles (UAVs) available at the Virginia Tech Laboratory for Coordination at Scale coordinated by Prof. Ryan K. Williams. In addition, in [A41], we further expanded our research concerning agents with a limited field of view by addressing two additional problems: i) rejection of sensor attacks; and ii) adaptive tuning of interaction gains. The former aspect focuses on the problem of endowing the multi-robot system with resilience to cyber-physical attacks, while the latter aspect focuses on the problem of overcoming a typical shortcoming of distributed control frameworks based on potential fields, i.e., the overall system behavior is highly sensitive to the gain assigned to relative interactions.

Coordinating large teams of robots can be accomplished in many ways, for example with robot swarms using decentralized techniques. In this regard, the research activity focused on the development of distributed techniques to let the desired collective behavior of the team (swarm behavior), emerge by means of local interactions under realistic working assumptions, such as for example the saturation of the actuators and the limited visibility range of the sensory system ([C30, C33, C39]). These cooperative swarm methodologies, initially developed for small ground mobile robots, have been also integrated with a virtual target-based path-following guidance system developed for marine surface vehicle systems in [C34]. Such a framework has then been enhanced by taking into account the vehicles' positive surge speed constraint and maximum limit, typical of marine systems in [C47]. This framework has been further refined in [A16] by introducing a swarm-base protocol for letting a team of Unmanned Surface Vehicles USVs converge to and navigate along a desired reference path, while at the same time aggregating and maintaining a range-based formation configuration. In addition, in [C69, A27] we addressed also the problem of progressively deploying a set of robots to a formation defined as a point cloud, in a decentralized manner by representing the target shape as an acyclic directed graph in which each robot can find its position using two other robots (called parents) in the shape as reference. By assuming the graph representation to be available to all robots, but none is initially assigned to a specific position, the overall shape is built dynamically and iteratively: each new robot joins the shape only after being granted permission by one of the parents, using local communication exclusively. The resulting algorithm is completely decentralized and parallel: multiple robots can join different parts of the shape at any given time.

Dealing with heterogeneous robotic networks in which each robotic agent might differ in terms of dynamics, and/or sensing and computation capabilities, the control strategy has also to deal with inherently combinatorial and discrete-event-driven problems. As a matter of fact, the overall control of the heterogeneous robotic network from a higher-level viewpoint is difficult, because the control system must simultaneously address task planning, dynamic task sequencing, resolution of conflicts for shared resources, and event-based feedback control. In this regard, in [C37, A22] we proposed a decentralized model and control framework for the assignment and execution of tasks, i.e. the dynamic task planning, for a network of heterogeneous robots. In particular, the proposed modeling framework allows the design of missions, defined as sets of tasks, in order to achieve global objectives regardless of the actual characteristics of the robotic network. The concept of skills, defined by the mission designer and considered as constraints for mission execution, is exploited to distribute tasks across the robotic network. In addition, we developed a decentralized control algorithm, based on the concept of skills for decoupling the mission design from its deployment, which combines task assignment and execution through a consensus-based approach.

A great challenge when dealing with the design of distributed coordination algorithms is endowing protocols with resilience and security against possible faults of sensors or actuators and against the threat of cyber-physical attacks. As a matter of fact, when dealing with distributed coordination, even though is generally true that there is inherent strength in numbers, unfortunately, it is also true that the behavior emerging from local interactions, through sensing or communication, is often extremely vulnerable to malfunction of single agents, i.e., a single agent can disrupt, accidentally or intentionally, the emergent behavior of a large-scale network by executing movements different from the nominal control action. In [A36] we addressed the dynamic resilient containment control problem for continuous-time multi-robot systems, i.e., the problem of designing a local interaction protocol that drives a set of robots, namely the followers, toward a region delimited by the positions of another set of robots, namely the leaders, under the presence of adversarial robots in the network. In particular, by assuming the multi-robot interactions to be described by an undirected graph, we proposed a distributed control protocol able to achieve the global objective under the presence of adversarial agents, which may arise from either faults or intentional cyber–physical attacks on the robotic network. In [A38], by considering a discrete-time multi-agent system interacting under a directed time-varying graph, we proposed a novel distributed local interaction protocol to achieve secure rendezvous or static containment within the convex hull of a set of leader agents. Notably, under the assumption that a set of anonymous adversarial agents may intrude on the network, we proved that the proposed strategy guarantees the achievement of the global objective despite the continued influence of the adversaries which cannot be detected nor identified by the collaborative agents.

The exploration of unknown environments by mobile robots has received attention for as long as there have been mobile robots as finding its way around is a fundamental capability a robotic platform must have. The problem has been well-studied with many different models for a single robot exploring the environment, under line-of-sight or distance-sensing constraints, in obstacle-dense or sparse environments, with various motion constraints, and many other model variants. The situation is much less clear for exploration by multiple robots. In [C8, A9], we considered the situation of multiple robots exploring an obstacle-dense environment, which is modeled as a graph, from a single starting vertex. The graph is initially unknown; the existence of edges becomes known only when a robot sees one end of the edge from a vertex, and the other end of the edge becomes known only when the robot actually follows that edge. In this way, we model an environment of sites with passages between them, where the passages are opaque: from either end, it is not clear where the passage goes. All edges have unit length, and each robot can follow one edge in each time step. For this setting, we proposed an algorithm, named MR-DFS, for the exploration of an unknown undirected graph, which is guaranteed to succeed on any graph, which is never worse than classical single-robot DFS, and which on trees we have proved to be optimal for two robots and have optimal dependence on the size of the tree, but not its radius, for k robots. The proposed algorithm needs only a local communication model, where communication happens only between a robot and a bookkeeping device left at that node, or between robots standing simultaneously at the same node.

B.2 Distributed Optimization and Decision-Making in Multi-Agent Systems

Distributed Optimization and Decision-Making in Multi-Agent Systems have gained momentum in the Control and Robotic communities over the last few decades. Scientific interest in this research topic is motivated by a wide range of applications including power systems, sensor networks, smart buildings, and smart manufacturing. In this regard, the research activity of Prof. A. Gasparri has focused on several aspects of distributed optimization and decision-making, including electric demand-side management, flow network balancing, workload balancing, Markov chain re-design, and time-varying optimization, multi-agents task allocation, and construction and partitioning of combinatorial rigid graphs.

Briefly, demand-side management (DSM) aims to manage the electric power demand to match baseload power generation, thus reducing the use of costly and polluting peaker power plants. The coordination of the power consumption of thermostatically controlled loads (TCLs) during daily peaks of urban power consumption is crucial to reduce costs. However, the time-correlation of consumers' power consumption combined with the penetration of volatile renewable generation has exposed the inadequacy of unidirectional DSM strategies. In [C62, A34], we provide a multi-agent control architecture and an online optimization method based on a dynamic average consensus to coordinate the power consumption of a large population of TCLs cooperating within a peer-to-peer (P2P) network autonomously and anonymously with a small set of neighboring agents in the network graph. The proposed method aims to exploit only local and asynchronous anonymous interactions among the agents to optimize through their emergent behavior a global objective function defined by their power consumption.

Balancing the flows over a network is a fundamental challenge in several contexts, ranging from infrastructure networks such as water or gas networks, to ecology, and from medicine to supply chain optimization. Applications, where balance plays a key role, include (among others) maximum flow problems, auction and energy minimization algorithms, complex network synchronization, distributed network adaptation, flow prediction strategies, and swarm guidance. Flow balance is also closely related to the double stochasticity of the matrix that characterizes the dynamics of distributed consensus algorithms, which find application in sensor networks and, in general, multi-agent systems where one is interested in distributively averaging measurements at each agent. In this regard, in [A28] we focus on finding the solution for the flow network balancing problem that is optimal in a minimal effort sense. More specifically, we aim at modifying a given set of (unbalanced) flows so that we obtain a balanced solution. We assume that there is a (possibly heterogenous) cost associated with the unit variation of each flow, as well as lower and upper bounds on the per-edge flows. More in detail, we first establish a necessary and sufficient optimality condition for network balancing and then propose a distributed protocol, demonstrating its convergence toward the global optimal solution.

Balancing the workload over a network is an important problem for a wide range of applications ranging from cloud computing to flexible manufacturing. While classical approaches consider scenarios where the workload distribution is carried out in a centralized fashion, in recent times, due to the increasing computational capability of computers and industrial machines and the pervasiveness of information and communication technologies, we are observing a paradigm shift from centralized to more agile and horizontal schemes, such as in the cases of Internet of Things and Industry 4.0, where entities cooperatively take decisions, with no need for central coordination. In [A40], we proposed a load balancing problem formulation where agents cooperate with the aim of simultaneously minimizing both the workload disparity among the agents and the overall workload transfer, under network capacity constraints. Notably in our setting, the problem shares the same sparsity pattern as the network, and this aspect allows solving it without the need for the agents to store large amounts of data. In particular, while the load-balancing process occurs over directed links, communication is assumed to be bidirectional. In detail, we first derive an optimality condition, then we design a provably convergent distributed algorithm to compute the optimal solution, and finally, we characterize an upper bound on the convergence rate.

Markov chains are an effective tool to model dynamic phenomena. In the context of networked and distributed systems, Markov chains have been successfully adopted to model a variety of applications; among others: fault-tolerance; packet losses; quality of service; distributed consensus. In this regard, in [C72] we formulated a problem where we aim at redesigning a Markov chain in order from one side to maximize the repulsiveness of a prescribed distribution and from another side to minimize the redesign effort. For this problem, which is encoded as an optimization problem, we provided a necessary and sufficient local optimality condition and a sufficient global optimality condition. This research has been extended in [A45] where we consider the problem of modifying in a distributed way the transition probabilities of a Markov chain over an undirected graph in order to achieve a desired limiting distribution while minimizing the variation from the original weights. Because of irreducibility and aperiodicity constraints, the problem is not directly solvable via traditional approaches, but we demonstrated that these constraints are always satisfied by the optimal solution of a relaxed problem, i.e., where such constraints are neglected. By suitably manipulating the Karush-Kuhn-Tucker conditions for the relaxed problem, we show that the global optimal solution corresponds to the zeros of a nonlinear and nonsmooth function. The proposed algorithm solves the problem by seeking a zero of such a function, relying on nonsmooth stability theory and, in particular, Filippov calculus. In this way, the algorithm has several benefits in terms of memory, communication cost, and convergence speed.

Cooperative multiagent systems involve a number of entities working together to collectively solve a problem or maximize utility. Two very-well known problem formulations that are based on cooperation among agents are opinion dynamics and consensus dynamics. Notably, opinion dynamics describes interaction models where the network topology changes over time according to how similar the opinion of the decision-makers is. On the contrary, consensus dynamics describes interaction models where the nature of the (time-varying) network topology is decoupled from the standpoint of the agents. In [A40], we considered an intermediate scenario, such as in the context of political decision-making, where i) a decision must necessarily be taken; ii) decision-makers usually have clashing opinions; and 3) alliances and compromises are typically established before voting. In particular, we considered a situation where players with ideas that satisfactorily mediate the standpoint of their interlocutors, i.e., players that do not need to modify too much their position to reach common ground, will end up being more influential in the overall decision-making process. For this setting, we proposed a distributed consensus algorithm where the final consensus is weighted according to the ability of each player to minimize the deviation from their initial standpoint.

Distributed optimization has emerged as an effective tool for solving large-scale problems, as typical for problem formulations coming from the fields of big data and artificial intelligence. Briefly, the multi-agent optimization paradigm considers a scenario in which the agents collaboratively minimize a global objective function made up of a sum of local objective cost functions subject to some local and/or global constraints. In this regard, in [C72] we considered the distributed optimization problem where the global objective for the multi-agent system is to minimize the sum of locally coupled strictly convex cost functions. Notably, this class of optimization objectives can be used to encode several important problems such as distributed estimation. For this problem formulation, we proposed a distributed discontinuous gradient descent algorithm, which can provably converge in finite time. This protocol relies on local observers to retrieve 2-hop state information, needed to compute the descent direction, and on adaptive gains, needed to render the convergence of the algorithm independent from: i) the structure of the network topology and ii) the local gains of the per-agent signed gradient-descent update law. In [C78], we developed a multi-agent distributed algorithm to solve a quadratic programming problem with linear time-varying constraints. We first considered the frozen-time optimization problem for which we derived a necessary and sufficient global optimality condition, then, we develop a continuous-time discontinuous algorithm that based on such condition can track the time-varying global optimal solution in finite-time. In [C87], we considered a global objective given by a weighted sum of local objectives, where each local weight encodes the absolute relevance of the per-agent local objective associated. In this setting, each agent is assumed to have only local (possibly inconsistent) information regarding the relative importance of its objective function with respect to its neighboring agents. Indeed, this could be exploited to model scenarios where only partial knowledge is available to each agent, e.g., for privacy reasons. In this regard, we propose a distributed framework where agents cooperate to both negotiate their absolute relevance and solve the resulting optimization problem in finite time under the assumption that the local objective functions are strongly convex, i.e., the Hessian matrix of each local objective function has eigenvalues that are lower bounded by a known positive constant. In [**?**], we developed a distributed algorithm to track in finite time the optimal solution for an unconstrained time-varying convex quadratic optimization problem where variability occurs in the linear term of the objective function, i.e., each agent holds a local quadratic objective function with a time-varying linear term, under the assumption that the local objective functions are strongly convex. In [A47], we addressed a time-varying quadratic optimization problem over a graph, where a different optimization setting is considered, i.e., the problem formulation must share the same sparsity pattern as the static graph encoding the undirected network topology over which the multi-agent system interact. Notably, this framework allows us to effectively model scenarios in which the optimization problem is inherently embedded within the network topology, e.g., flow balancing, electrical power system management, or packet routing problems. In this regard, we proposed a finite-time distributed algorithm that allows tracking the time-varying optimal solution over time.

Task allocation represents a fundamental building block for collaborative multi-robot systems. In order to achieve high-level autonomous goals and cope with dynamic environments, task allocation models and optimization methods are required that are efficient, scalable, and expressive. Otherwise, allocation plans for multi-robot teams may be intractable or lack sufficient mission complexity. Over the years, a great amount of research has been carried out in the task allocation area within the robotics community. In [C64], we demonstrated how abstract constraints can be integrated into task allocation by applying the combinatorial theory of matroids. Furthermore, we introduced a novel task allocation problem that coupled abstract per-robot constraints with a communication-spanning tree constraint. As a matroid intersection problem, provable optimality bounds with simple greedy algorithms were derived immediately from matroid theory. We then presented a decentralized algorithm that applies auction methods to task allocation with matroid intersections. In [C82], by resorting to this modeling paradigm, we proposed an allocation and scheduling framework to assign farming operations to both robotics platforms and human operators.

Broadly speaking, the notion of rigidity represents an important requirement when the task demands collaboration among teammates. Its relevance is clear in the context of controlling formations of mobile nodes when only relative sensing information is available, i.e., the asymptotic stability of a formation is guaranteed when the graph that defines the formation is rigid by construction. Rigidity becomes a necessary (and in certain settings sufficient) condition for localization tasks with distance or bearing-only measurements, e.g., it can be shown that if the rigidity conditions for localizability for traditional noiseless systems are satisfied, and measurement errors are small enough, then the network will be approximately localizable, providing a connection between robustness and rigidity. Therefore, it appears relevant to develop strategies for constructing optimally rigidity graph. In this regard, in [C44, A20], we considered the topology optimization problem under a graph rigidity constraint. We formulated the optimally rigidity graph construction as a constrained combinatorial optimization problem and we demonstrated that by resorting to matroid optimization theory we could prove that a greedy edge evaluation will ultimately yield a provably (sub)optimal solution for our problem formulation. More specifically, we proposed two auction-based algorithms to solve this problem in a decentralized fashion centered around the notion of leader election. The first approach was proven to find an optimal solution through greedy bidding, while the second approach was proven to find a sub-optimal solution that reduces complexity according to a sliding mode parameter for which we developed a closed form of the maximum gap between the optimal solution and the sub-optimal solution. In [C53, A17], motivated by the collaborative impact of rigidity, we consider the problem of partitioning a multiagent network into two sub-teams, that is *a bipartition*, such that the resulting sub-teams are topologically rigid. In this direction, first, we determined the existence conditions for rigidity-preserving bipartitions, and then, we developed an iterative algorithm that identifies such partitions in polynomial time. Furthermore, we describe how to achieve decentralization of the proposed algorithm by exploiting leader election and a heuristically pruned depth-first search (DFS).

B.3 Distributed Estimation in Multi-Agent Systems

Distributed Estimation in Multi-Agent Systems has been a very popular research field in the Control and Robotic communities for a long-time. The interest towards this research topic can be explained by the broad spectrum of possible applications ranging from data fusion for monitoring tasks in sensor networks to information sharing for achieving collaborative tasks in multi-robot systems. In the context of distributed estimation, agents cooperate by means of local interaction rules in order to allow the computation of global information usually not locally available to any of them, such as for example information regarding underlying properties of the graph encoding the multi-agent network topology. In this regard, the research activity of Prof. A. Gasparri has focused on several aspects of distributed estimation in multi-agent systems, including data fusion, consensus-based protocols, gossip-based protocols, and a distributed framework for k-hop control strategies in large-scale networks.

Data fusion is a research area that is growing rapidly due to the fact that it provides means for combining pieces of information coming from different sources/sensors. As a result, an enhanced overall system performance, i.e., improved decision-making, increased detection capabilities, diminished number of false alarms, and improved reliability, with respect to separate sensors/sources, can be achieved. Indeed, data fusion techniques play an important role in the context of multi-agent systems where information coming from different sources must be aggregated in order to provide a meaningful description of the surrounding environment. In [A8], we propose an extension of the transferable belief model (TBM) to a multi-agent distributed context where no central aggregation unit is available and the information can be exchanged only locally among agents. In this framework, agents are assumed to be independent reliable sources that collect data and collaborate to reach common knowledge about an event of interest. In particular, TBM introduces the idea of open-word assumption in the DS framework. This implies the set of hypotheses is not to be exhaustive; therefore, information can be contradictory. Indeed, the concept of contradiction is a powerful tool to detect cases where information fusion has to be considered unreliable, a case that is not considered in the Bayesian technique. This framework originally developed for network topologies described by a tree has been generalized to network topologies described by a graph in [C26].

The consensus problem, i.e., the problem of having all agents eventually reach an agreement upon a common quantity of interest, has proven to be a fundamental component for the design of distributed coordinated control strategies in the context of multi-agent systems. This has attracted tremendous attention within the Control and Robotics communities from both theoretical and practical perspectives. In this context, the research activity of Prof. A. Gasparri has focused on the development of novel distributed protocols for solving consensus problems under particular working conditions, e.g., a given graph structure or communication model, and for solving other problems by resorting to consensus-based strategies, e.g., clock synchronization or common reference frame estimation.

As far as the consensus problem is concerned, in [A12, A18, A19], we considered a general scenario where the communication among the agents is modeled as a directed graph and two different communication schemes are considered: i) point-to-point, i.e., a communication mechanism where an agent (sender) transmits a specific message to another agent (receiver), selecting exactly an agent among all of his neighbors; and ii) broadcast, i.e., a communication mechanism where an agent (sender) can simply transmit a message which will be received by any other agent (receivers) within its range of transmission. In this regard, we developed a distributed algorithm that is to compute the average consensus over any strongly connected weighted digraph. The main contribution was the introduction of the first average consensus protocol suitable for an implementation based on a pure broadcast communication scheme over a strongly connected weighted digraph. Notably, this represents a significantly better choice compared to a point-to-point communications scheme, since it can be more easily implemented and provides higher robustness to the system. In [C63, A29], we proposed a novel local interaction protocol that solves the discrete time dynamic average consensus problem, i.e., the consensus problem on the average value of a set of time-varying input signals in an undirected graph. The proposed interaction protocol is based on a multi-stage cascade of dynamic consensus filters which tracks the average value of the inputs with small and bounded errors. We characterized its convergence properties for time-varying discrete-time inputs with bounded variations. The main novelty of the proposed algorithm is that, with respect to other dynamic average consensus protocols, we obtain the next unique set of advantages: i) the protocol, inspired by proportional dynamic consensus, does not exploit integral control actions or input derivatives, thus exhibits robustness to re-initialization errors, changes in the network size and noise in the input signals; ii) the proposed design allows to trade-off the quantity of information locally exchanged by the agents, i.e., the number of stages, with steady-state error, tracking error and convergence time; iii) the protocol can be implemented with randomized and asynchronous local state updates and keep in expectation the performance of the discrete-time version. In [A49], we further extended this framework by combining the multi-stage cascade of dynamic consensus filters with a second-order diffusive protocol. The former overcomes the need of k-th order differences of the inputs and conservation of the network state average, while the latter overcomes the trade-off between speed and accuracy of the sequence of consensus stages by just storing the previous estimate at each node. The result is a protocol that is fast, arbitrarily accurate, and robust against input noises and initializations. The protocol is also extended to an asynchronous and randomized version that follows a gossiping scheme that is robust against potential delays and packet losses. In [A30], we considered a scenario where agents move according to independent random walks over a given location graph, where vertexes denote locations and edges describe the existence of a connection between them. Compared to classical gossip schemes, where the underlying interaction graph is fully connected and pair-wise interactions occur over time according to some probability distribution, in our setting the interaction graph is not determined a priori, but it is the result of proximity- based local interactions modeling the fact agents must necessarily be sharing the same location in order to exchange information. The main contribution of the proposed approach was twofold: (i) we characterized the time-varying pairwise communication probabilities among the agents, which are driven by independent random walks over the location graph; (ii) we proved the convergence of the proposed gossip dynamics in expectation (in terms of first moment and second moment) to the average of the initial conditions of the agents.

As far as the clock synchronization problem is concerned, in [A21] we advanced the state of the art by providing a solution to the clock synchronization problem for wireless sensor networks under the assumption of (random) bounded communication delays has been addressed. In particular, we proposed a novel robust protocol consisting of two asynchronous consensus-based algorithms for the synchronization of the clocks' frequency and offset. We provided a theoretical analysis of the convergence and robustness properties of the proposed algorithm along with experimental results to corroborate the theoretical analysis, evaluate the scalability of the proposed clock synchronization algorithm and show its effectiveness in a real-world scenario. In addition, in [A13] we proposed a novel wireless sensor network synchronization protocol for event-driven measurement applications in order to: i) provide high accuracy in the area where an event is detected and; ii) ensure a long network lifetime. The complexity of the problem arises from the fact that these two properties are usually in conflict as: i) to increase the synchronization accuracy, nodes are required to exchange synchronization packets at a higher rate, thus impacting the network lifetime; while ii) to ensure a long network lifetime, the number of packets to be exchanged should be minimized thus impacting the synchronization accuracy. Notably, a tradeoff can be achieved by observing that the packet rate should be increased only for the portion of the network surrounding the detected events as only these nodes require a higher accuracy to collect data. The proposed algorithm represents a formalization of this idea. We provided a theoretical characterization of the convergence properties of the proposed algorithm along with experimental results to confirm the effectiveness of the proposed framework in a real WSN testbed.

Prof. A. Gasparri research activity has focused also on the development of *service protocols* which are meant to provide useful information for simplifying the design of multi-agent coordination strategies. In this regard, the main contributions concern: i) the design of continuous-time distributed protocols for estimating the spectral properties of a graph [C13, A10]; ii) the design of a gossip-based protocol for computing the centroid and common reference frame of a multi-agent system [C35, A14]; iii) the design of discrete-time protocols for estimating topological properties of a graph such as node-centrality [C71, A33]; iv) the design of distributed protocols for evaluating the rigidity of a planar network, while satisfying common objectives of real-world systems such as decentralization, asynchronicity, and parallelization [C44, A15]; v) the development of a distributed framework for k-hop control strategies in large-scale networks based on local interactions [C67, A31]; vi) the design of a discrete-time protocol to compute the mode of the agents initial values, i.e., the value with largest cardinality [A44]; vii) the design of a distributed continuous-time protocol for tracking in finite-time the minimum (or maximum) among the infimum (or the supremum) of a set of exogenous signals, each of which is locally available only to one agent of the network [C88, A46].

B.4 Robotics and Control Methodologies for Precision Agriculture

Precision agriculture (PA) is a modern whole-farm management concept that exploits several technologies ranging from remote sensing and proximal data gathering to automation and robotics. PA is expected to increase the quantity and quality of agricultural output while using less input (water, energy, fertilizers, pesticides, etc.), that is in other words, to produce more and better food, sustainably, while saving costs and decreasing the environmental footprint of agriculture, thus addressing the three major challenges that can be currently identified when looking at the agri-food sector: i) feeding a growing population; ii) providing a livelihood for farmers and farm workers, and iii) protecting the environment. In this regard, the research activity of Prof. A. Gasparri has focused on several aspects concerning the precision farming paradigm, ranging from the design of the navigation, planning, and coordination strategies for deploying robotic platforms within an agricultural setting to the design of complete frameworks for automatizing farming operations and enhancing monitoring over large-scale orchards.

As far as the autonomous navigation of robotic platforms in precision farming settings is concerned, we considered a challenging agricultural setting where an autonomous farming robot is required to navigate within an orchard to collect information and perform agronomic interventions at the resolution of the single tree. In particular, motivated by the needs of the H2020 project PANTHEON, we considered a robotic platform with Ackermann steering kinematics which is moving within a hazelnut orchard. To this regard, in [A32] we proposed a navigation stack for the autonomous navigation of Ackermann steering vehicles in precision farming settings with two main components, namely a local planner and a pose regulation control law. Briefly, the local planner generates, in real-time, optimal trajectories by taking into account both the Ackermann kinematics and the obstacles (e.g. trees, rocks, etc.) that might lie, or dynamically appear, along the route. To do so, the planning problem is modeled as a cost-function minimization problem over a finite-time horizon, and by re-planning the optimal trajectory in a receding horizon fashion. The outcome of the local planner, i.e., a trajectory described by a sequence of desired poses, is then fed into a non-smooth control law that ensures the convergence toward each of these configurations. This control law, which is inspired by control techniques originally applied to the unicycle kinematics, has been purposely designed ex novo to solve the pose regulation problem for vehicles with Ackermann kinematics. A comprehensive theoretical characterization of the convergence properties of the pose regulation controller is also provided by resorting to tools coming from non-smooth theory. The proposed navigation stack has been validated through real-world experiments within the H2020 project PANTHEON, i.e., within a real-world (1:1 scale) hazelnut orchard located in Caprarola, Italy.

As far as the design of planning and coordination strategies of robotic platforms tailored for agricultural settings is concerned, the research has considered scenarios involving both aerial and ground vehicles. In [A42], we proposed a novel information-based mission planner for a drone tasked to monitor a spatially distributed dynamical phenomenon. This work is motivated by the observation that due to the spatiotemporal dependencies of the observed phenomenon, the estimation process does not necessarily require collecting data over the entire field, which would be prohibitive for UAVs due to their limited autonomy. Differently, it is possible to resort to filtering techniques, e.g., Kalman filtering, to accomplish the task. In this regard, the trajectory planning problem can be stated as the problem of generating a flight plan that maximizes the quality of the state estimation while satisfying the flight constraints (e.g., flight time). In [A43], we consider a farming scenario where a set of agricultural tasks must be performed by a fleet of heterogeneous robotic platforms at specific locations. To formulate this problem we propose a multi-Steiner Traveling Salesman Problem (TSP) formulation by extending the Steiner TSP to i) multiple heterogeneous mobile robots and ii) allowing to visit only a subset of all possible locations within the field, as typical for PA settings. In addition, we provide a sub-optimal formulation to mitigate the computational complexity of the multi-Steiner TSP by leveraging the fact that generally in PA settings only a few locations require agricultural tasks in a certain period of interest compared to all possible locations in the field. A formal analysis of the optimality gap between the optimal and the sub-optimal formulations is provided as well.

As far as the design of complete frameworks for automatizing farming operations and enhancing monitoring over large-scale orchards is concerned, the research has focused on the problem of managing hazelnut suckering plants on a per-plant basis in a large-scale orchard. Briefly, suckering plants, or shortly, suckers, are basal shoots that grow at the base of a tree and compete with the tree itself for nutrients and water. Generally, in large-scale orchards, suckers are treated with the application of herbicide through spraying tractors that continuously spray the crops while navigating the whole orchard. Notably, this approach does not consider the individual needs of each plant and it is definitely not environmentally friendly since a lot of unnecessary solution is being drained in the soil. For this reason, in [A48] we proposed an autonomous spraying robot architecture for sucker management in large-scale hazelnut orchards that allows for significantly reducing pollution and waste. More specifically, this architecture allows: i) the detection of the presence of suckers for each plant, by relying on a You Only Look Once (YOLO)-based recognition system; ii) the reconstruction of suckers in three-dimension; and iii) the estimation of the amount of herbicide solution needed for the specific plant, based on a data-driven approach. The herbicide solution is applied using a ground robot equipped with an RGB-D camera and a spraying system. The proposed architecture has been validated through real-world experiments within the H2020 project PANTHEON, i.e., within a real-world (1:1 scale) hazelnut orchard located in Caprarola, Italy

In addition, the research has focused also on some aspects concerning the technological limitations of rural areas. As a matter of fact, the networking facilities in most of the remote agriculture farms are not robust and are subject to network congestion and extreme weather conditions that often make the cloud-centric execution of robotic applications infeasible for latency-sensitive tasks, especially when the faster exchange of data among the robots and cloud datacentres residing at a multi-hop distance is mandatory. To address these limitations, the concept of edge computing represents a viable solution. Edge computing extends the data processing and storage facilities in the proximity of the data source and consequently reduces network delay. In the context of agriculture, edge resources are referred to as local servers, robots, and networking devices, including access points and gateway routers, which exhibit limited processing capability to support the execution of agricultural applications on a farm. Thus, they are capacity-constrained in terms of processing cores and storage and heterogeneous in processing speed. In [A35] we focused on the Quality-of-Service (QoS)-aware computational resource allocation problem for edge computing infrastructure using a game theoretic model. Notably, the proposed resource allocation mechanism can run heterogeneous data processing tasks of multiple applications within the deadline and energy constraints of the resources. In this regard, our contribution is threefold: i) we designed an edge computing framework to support robots and humans in precision farming settings for executing multiple agricultural applications, overcoming the limitations of the cloud during latency-sensitive interactions; ii) we developed a congestion game-theoretic mechanism to solve the computational resource allocation problem in the edge computing environment, which jointly minimizes the task completion time of multiple applications and the energy consumption of resources to maintain the Quality-of-Service (QoS); and iii) we conducted a theoretical analysis to demonstrate the finite improvement property of the modeled game, particularly the attainment of Nash Equilibrium state for the proposed resource allocation mechanism.

C Collaboration

C.1 National

2017–Present	Responsible for scientific collaboration with the Complex Systems and Security Lab at the Campus Bio-Medico University of Rome on issues related to distributed optimization for multi-agent systems. Since 2017, the collaboration, which mainly involved Prof. Gabriele Oliva and Prof. Roberto Setola, has produced 8 article article published to international journals and 11 articles published on international conferences.
2016–Present	Responsible for the scientific collaboration with Prof. Alessandro Marino at the University of on issues related to the design of distributed observatories for large-scale systems and on cooperative optimization issues. Since 2016, the collaboration has produced 2 article published to international journals and 4 articles published on international conferences.
2012–Present	Responsible for scientific collaboration with the Automation, Robotics and Systems Control (ARS) group of the University of Modena and Reggio Emilia on issues related to connectivity control for multi-robot systems. Since 2012, the collaboration, which involved Prof. Lorenzo Sabattini and Prof. Cristian Secchi, has produced 2 articles published in international journals and 2 articles published in international conferences.
2009–Present	Responsible for scientific collaboration with the Automatic Control group of the University of Cagliari on issues related to distributed coordination for multi-agent systems. Since 2009, the collaboration, which mainly involved Prof. Mauro Franceschelli and Prof. Alessandro Giua, has produced 7 articles published on international journals and 9 articles published on international conferences.

C.2 International

2016–Present | Responsible for scientific collaboration with the research group coordinated by Prof. Ryan K. Williams at the Virginia Tech Department of Electrical and Computer Engineering on issues of coordination and optimization of multi-robot systems with direct interactions. Prof. A. Gasparri was invited professor at Virginia Tech's Department of Electrical and Computer Engineering from 07/19/2017 to 08/07/2017. Furthermore, Prof. A. Gasparri, in collaboration with Prof. Ryan K. Williams, was the promoter of a MoU (Memorandum of Understanding) with Virginia Tech for the exchange of professors and researchers as well as students and for the organization of joint research. Since 2016, the collaboration has produced 3 articles published in international journals and 6 articles published on international conferences, including one finalist for the Best Multi-Robot Systems Paper Award at the 2017 IEEE International Conference on Robotics and Automation (ICRA 2017).

2013–Present | Responsible for scientific collaboration with the Autonomous Networks Research Group coordinated by Prof. Bhaskar Krishnamachari at the University of Southern California (USC), in Los Angeles, USA on issues related to the integration of multi-robot systems with sensor networks. Prof. A. Gasparri was visiting from 21/05/2013 to 30/06/2013 within the Distinguished Visiting Fellow Program the Ming Hsieh Institute (MHI) of the Department of Electrical Engineering of the USC Viterbi School of Engineering. Since 2013, the collaboration has produced 2 article published in an international journals, 1 book chapter and 3 articles published in international conferences.

2012–Present | Responsible for the scientific collaboration with the Robotics team coordinated by Prof. Gaurav Sukhatme at the University of Southern California (USC), in Los Angeles, USA on coordination issues for multi-robot systems. As part of the scientific collaboration, Prof. A. Gasparri has mentored and co-supervised the PhD student Ryan K. Williams (advisor Prof. Gaurav Sukhatme) at the University of Southern California on issues related to multi-robot coordination, with particular regard to to the problem of distributed topology control. The topics covered by the collaboration became part of the doctoral thesis and produced 4 articles published in international journals and 5 articles published in international conferences.

2012–Present | Responsible for scientific collaboration with the Robotics group, Perception and Real Time Group (GRTR) coordinated by Prof. Carlos Sagüés at the Universidad de Zaragoza on issues of coordination and distributed estimation for multi-agent systems. As part of the scientific collaboration, Prof. A. Gasparri proposed the visit to the GRTS and coordinated the research activities for the PhD student A. Priolo (visiting from 30/04/2012 to 31/10/2012), which lead to the publication of 2 articles published in international journals and 2 articles published in international conferences. Since 2012, the collaboration, which mainly involved Prof. Eduardo Montijano and Prof. Carlos Sagüés, has produced 4 articles published in international journals and 3 articles published in international conferences.

2011–Present Responsible for scientific collaboration with the research group coordinated by Prof. Emanuele Garone at the Service d'Automatique et d'Analyse de Systemes (SAAS) of the Université Libre de Bruxelles (ULB), where Prof. A. Gasparri is officially affiliated as a Collaborateur Scientifique from 01/01/2018, on issues of distributed clock synchronization for sensor networks, distributed coordination for multi-robot systems and Robotics and Control Methodologies for Precision Agriculture. The collaboration has led over the years to the joint supervision of degree theses, internships, and the joint supervision of a PhD (Dr. Nicolás Bono Rosselló) within the H2020 Precision Farming for Hazelnut Orchard project, of which Prof. A. Gasparri is the coordinated and Prof. Garone is responsible for the ULB unit. In particular:

- Dr. Mouhamad Haidar Lakkis has visited the NEWLINE Research group at Roma Tre University for an internship from 27/06/2019 to 21/09/2019 to work on a point-cloud based plant canopy volume estimation;
- Dr. Benjamin Wauthion has visited the NEWLINE Research group at Roma Tre University for an internship from 09/07/2018 to 19/10/2018 to work on a simultaneous localization and mapping filter for UGV in ROS Gazebo;
- Dr. Alessandro Raguzzi has visited the SAAS from 01/09/2018 to 24/12/2018 to carry out part of his master thesis focused on the ground robot motion planning for large-scale hazelnut orchard monitoring;
- Dr. Silvia Liuzzi has visited the SAAS from 02/04/2016 to 24/09/2016 to carry out part of her master thesis focused on the coordination of multi-agent systems with asynchronous interactions;
- Dr. Letizia Di Giulio has visited SAAS from 29/03/2014 to 01/08/2014 to carry out part of her master thesis focused on the coordination of multi-robot systems for the collaborative transport of bar-shaped objects;
- Prof. A. Gasparri was co-supervisor of the master's degree thesis of Dr. Celine Depouhon at ULB with topics on training control for multi-robot systems and closed-ended analysis of balance configurations.

Prof. A. Gasparri was visiting SAAS from 10/04/2012 to 03/05/2012 for a formal teaching assignment within the Lifelong Learning Program (LLP) -Erasmus, Individual Teaching Program for Teaching Staff Mobility. Since 2011, the collaboration has produced 6 articles published in international journals and 9 articles published in international conferences, including one Young Author Award at the 6th IFAC Conference on Sensing, Control and Automation Technologies for Agriculture (AGRICONTROL 2019).

X Academic Service

A Membership of Scientific Societies

2021–Present	**Committee Member**, Technical Committee on "IEEE TC Agricultural Robotics" of the IEEE Robotics and Automation Society
2019–Present	**IEEE Senior Membership**
2015–Present	**Committee Member**, Technical Committee on "Networks and Communication Systems" of the IEEE Control Systems Society
2014–Present	**Steering Committee Member**, Technical Committee on "Multi-Robot Systems" of the IEEE Robotics and Automation Society
2009–Present	IEEE Professional Membership

B Workshops and Tutorial Organization

2016	**Co-Organizer** of the Workshop "Taxonomies of Interconnected Systems: Large-Scale Networks", 55th IEEE Conference on Decision and Control (CDC 2016) / roughly 50 participants / Las Vegas – USA.
2015	**Co-Organizer** of the Workshop "Taxonomies of Interconnected Systems: Partial and Imperfect Information in Multi-Agent Networks", 54th IEEE Conference on Decision and Control (CDC 2015) / roughly 40 participants / Osaka – Japan.
2015	**Co-Organizer** of the Workshop "Taxonomies of Interconnected Systems: Asymmetric Interactions in Distributed Robotics", IEEE International Conference on Robotics and Automation (ICRA 2015) / roughly 50 participants / Washington – USA.
2015	**Co-Organizer** of the Workshop "Taxonomies of Interconnected Systems: Asymmetry and Directedness in Multi-Agent Interactions", The 2015 American Control Conference (ACC 2015) / roughly 40 participants / Illinois – USA.
2014	**Co-Organizer** of the Workshop "Taxonomies of Interconnected Systems: Topology in Distributed Robotics", IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2014) / roughly 50 participants / Illinois – USA

C Technical Program Committees (Partial List)

2016	13th International Symposium on Distributed Autonomous Robotic Systems (DARS '16)
2015	The 14th International Conference on Information Processing in Sensor Networks (IPSN 2015).
2014	The 11th European Conference on Wireless Sensor Networks (EWSN 2014).
2014	RoboSense 2014: The International Workshop on Cooperative Robots and Sensor Networks
2014	3rd Workshop on Visual Control of Mobile Robots (part of the IEEE Conference IROS 2014)
2010	10th International Symposium on Distributed Autonomous Robotic Systems (DARS '10)

D Conference Reviewer (Partial List)

- IEEE Control and Decision Conference (CDC)
- IEEE International Conference on Robotics and Automation (ICRA)
- IEEE International Conference on Intelligent Robots and Systems (IROS)
- IEEE American Control Conference (ACC)

E Journal Reviewer (Partial List)

- IEEE Transactions on Robotics (IEEE T-RO)
- IEEE Transactions on Automatic Control (IEEE TAC)
- IEEE Transactions on Mobile Computing (IEEE TMC)
- IFAC Automatica
- IEEE Transactions on Network Science and Engineering (IEEE TASE)
- IEEE Systems Journal (IEEE ISJ)
- IEEE Transactions on Control of Network Systems (IEEE TCNS)
- IEEE Transactions on Control Systems Technology (IEEE TCST)

XI Grants (Research Projects)

A National

Title: AGR-o-RAMA: “Precision Agriculture with Autonomous Robots for Active Monitoring”
Role: Roma Tre Unit Local PI
Amount: 149.986, 87 € (total), 49.378, 90 € (Roma 3)
Call: POR FESR Lazio 2014-2020 (Avviso Pubblico Progetti Gruppi Di Ricerca 2020)
Period: April 2021 - October 2023
Abstract: AGR-o-RAMA project proposes the development of autonomous drone swarms for monitoring extended agricultural fields, exploiting online planning and drone collaboration for active field monitoring. Active monitoring implies that each drone can decide where to move and what to observe, based on an estimate of the level of interest in the observed area. This allows obtaining high-resolution data only in the areas of greatest interest, while less relevant areas are observed with less accuracy. In addition, the ability to observe the same point of interest from multiple perspectives allows for three-dimensional reconstruction. The goal is to provide a multiple-resolution, 3D map of the field, where features of interest can be appropriately labeled, for example differentiating between normal or pathological situations. The techniques developed will be adapted to a case study relevant to Lazio: viticulture.

Title: PARADISE: “Precision fARming for sustAinable proDuctIon in Suburban arEas”
Role: Roma Tre Unit Local PI
Amount: 455.652, 26 € (total), 74.599, 07 € (Roma 3)
Call: POR FESR Lazio 2014-2020
Period: September 2020 - August 2022
Abstract: On 1 June 2018 the European Commission presented to the Parliament and to the European Council the legislative proposals for the reform of the Common Agricultural Policy valid for the period 2021-2027 in order to pursue the objective of agriculture capable of resisting changes (especially those of the market), which is sustainable, and which guarantees the vitality of rural areas through greater synergies with policies and the most incisive research and innovation initiatives by increasing the use of new technologies in agriculture, still not widespread throughout the EU, especially by small and medium-sized enterprises. In this regard, the project PARADISE, which fits within the GREEN ECONOMY specialization area, aims to study the development of peri-urban agricultural areas, in order to guarantee: i) an appropriate integration with the social and urban fabric, ii) a production process based on the paradigm of precision agriculture that is effective and respectful of the environment, and iii) energy sustainability from renewable sources of the technological infrastructure to support the production process

Title: NECTAR: “NEtworked Cooperative Teams of Autonomous Robots”

Role: Co-PI

Amount: 431,000.00 € (total), 215,500.00 € (Roma 3)

Call: FIRB “Futuro in Ricerca 2008”

Period: December 2010 - November 2014

Abstract: The NECTAR project is aimed at coordinating the research activity of two research Units of the Italian Community of Control Engineering (from the University of Cassino and the University of Roma Tre) on control issues for networked robotic systems. In particular, the NECTAR project wants to investigate and develop innovative techniques for the control of networked and cooperative robotic systems, i.e., teams of autonomous vehicles that, in order to achieve a common goal, cooperate by exchanging information via wireless communication. The project activities will be focused on the development of motion control techniques for a team of mobile robots that has to carry out coordinated missions both in an environment lacking a communication infrastructure (or sensor network) and in an environment where these infrastructures are available. In the first case, motion control techniques that allow the robots to achieve coordinated missions while preserving the established connectivity will be investigated. In the second case, techniques to integrate the team of robots with an infrastructure providing communication or additional sensor information will be analyzed and developed. The strategies developed during the project will be implemented and tested by exploiting the experimental setups already available at the Research Units and/or by using the equipment that will be expressly bought for the project purposes. In particular, the multi-robot team available at the Laboratory of Industrial Automation of the University of Cassino and the multi-robot team along with the sensor network available at the Robotics and Sensor Fusion Laboratory of the University of Roma Tre will be used.

B European

Title: "CANOPIES – A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems"

Role: Principal Investigator

Amount: 6.904.940, 00 € (total), 910.960, 0 € (Roma 3)

Call: H2020-ICT-2018-20 (H2020-ICT-2020-2)

Period: January 2021 - December 2024

Abstract: In CANOPIES, our goal is to develop a novel collaborative human-robot paradigm addressing the challenges of Human-Robot Interaction and Human-Robot Collaboration in the unstructured highly dynamic outdoor environment of permanent crop farming (Agri-Food Area). Our approach will be demonstrated through an integrated system composed of farming robots and logistics robots with a real-world validation of two economically relevant agronomic operations within a table grape vineyard: harvesting and pruning. CANOPIES represents the first attempt to introduce a collaborative paradigm in the field of precision agriculture for permanent crops where farmworkers can efficiently work together with teams of robots to perform agronomic interventions, like harvesting or pruning in table-grape vineyards. Both operations require complex processes of perception, communication, shared planning in agreement, prediction of human intentions, interaction, and action. But also, both agronomic operations should be done in real-life conditions, that is, in changing illumination and cast shadows, changing agronomic situations, where the vine branches or grapes can make it difficult to harvest or prune in a safe manner, due to the robot physical proximity to the human, while operating in real-time. CANOPIES ambition will be achieved by introducing: i) novel human-robot interaction methodologies for enhanced safety and coexistence, ii) novel human-robot collaboration methodologies for increased system adaptability and intuitive usability; iii) novel multi-robot coordination methodologies for improved scalability. CANOPIES impact will contribute to filling the current gap in the development of fully autonomous robotic solutions for permanent crops by introducing a novel concept of farming robots, where we leverage an effective interaction with the human workers to mitigate the greater complexity of permanent crops as compared with field crops.

Title: "PANTHEON – Precision Farming of Hazelnut Orchards"
Role: Coordinator and Principal Investigator
Amount: $3,144,452.50$ € (total), $960,893.75$ € (Roma 3)
Call: H2020-SFS-2016-2017 (H2020-SFS-2017-1)
Period: November 2017 - October 2021
Abstract: The goal of PANtHEOn is to develop the agricultural equivalent of an industrial Supervisory Control And Data Acquisition (SCADA) system to be used for the precision farming of large orchards of hazelnut (Corylus avellana L.). By taking advantage of the technological advancements in the fields of robotics, remote sensing and big-data management, our objective is to design an integrated system where a relatively limited number of heterogeneous unmanned robotics components (including terrestrial and aerial robots) move within the orchards to collect data and perform some of the most common farming operations. The information will be stored in a central operative unit that will integrate the data coming from the different robotic units to perform automatic feedback actions (e.g. to regulate the irrigation system) and to support the decisions of agronomists and farmers. We expect that the proposed SCADA system will be able to acquire information at the resolution of the single plant. This will permit to drastically increase the detection of possible limiting factors for each individual plant, such as lack of water or pests and diseases affecting the plant health, and to react accordingly. Compared to the current state of the art in precision farming, we believe that the proposed SCADA infrastructure represents a relevant step ahead in the context of orchard management. In fact, the capability of monitoring the state and the evolution of every single tree will be the enabling technology to allow more focused interventions. This will result in a better average state of health of the orchard, and in an increased effectiveness of Integrated Pest Management (IPM). In conclusion, the main advantages of this architecture are: i) an increase in hazelnut production; ii) a decrease in chemical inputs usage; iii) Environmentally-friendly water usage; and iv) Simplified orchard management. The outcome of the project will be validated through a final demo on a real-world (1:1 scale) hazelnut orchard.

Title: "ATENA – Advanced tools to assess and mitigate the criticality of ICT components and their dependencies over Critical Infrastructures"
Role: Roma 3 Unit Member
Amount: $6,890,000.00$ € (total), $857,500.00$ € (Roma 3)
Call: H2020-DS-2014-2015 (H2020-DS-2015-1)
Period: May 2016 - April 2019
Abstract: Over recent years, IACS (Industrial and Automation Control Systems) and SCADA (Supervisory Control and Data Acquisition) systems adopted in Critical Infrastructures (CI), such as smart grids, water, oil, and gas distribution networks, have become more complex due to the increasing number of interconnected distributed devices, sensors and actuators, often widely dispersed in the field, and the larger amount of information exchanged among system components. Such systems need to be flexibly and securely configured, monitored, and managed to prevent the increase of risks due to both operational errors and cyber-attacks, including intrusions and malware that could compromise their operations or even result in disasters. Within this framework, the project proposes an innovative and modernized logical framework with design improvements of role, operation, architecture, and security components for IACSs, exploiting also Software Defined Networking and Software Defined Security paradigms, and recommends equipment and algorithms devoted to patching already existing IACSs without the disruption of current services.

Title:	"CockpitCI - Cybersecurity on SCADA: risk prediction, analysis and reaction tools for Critical Infrastructures"
Role:	Roma 3 Unit Member
Amount:	$4,339,000.00$ € (total), $399,760.00$ € (Roma 3)
Call:	FP7-SEC-2011-1 (FP7-SEC-2011.2.5-1)
Period:	January 2012 - December 2015
Abstract:	CockpitCI aims to improve the resilience and dependability of Critical Infrastructures (CIs) through the automatic detection of cyber threats and the sharing of real-time information about attacks among CI owners. CockpitCI aims to identify, in real-time, the CI functionalities impacted by cyber-attacks and assess the degradation of CI-delivered services. CockpitCI aims to classify the associated risk level, broadcast an alert at different security levels and activate a strategy of containment of the possible consequences of cyber-attacks. CockpitCI aims to leverage the ability of field equipment to counteract cyber-attacks by deploying preservation and shielding strategies able to guarantee the required safety.

XII Publications

A Theses

[Th1] Andrea Gasparri. *Implementazione di un sistema Linux Real-Time per lo sviluppo di algoritmi di navigazione sensor-based*. PhD thesis, Roma Tre University, Via della Vasca Navale, 79, Roma, 5 2004. English Title: "Design of a Real-Time Linux Framework for the Development of Sensor-based Navigation Algorithms.

[Th2] Andrea Gasparri. *The Localization Problem: from Robotics to Sensor Networks*. PhD thesis, Roma Tre University, Via della Vasca Navale, 79, Roma, 4 2008.

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