ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

DET - The Extended Robot Mind: Engineering Collective Intelligence for Scalable Autonomy

Funded By	Dipartimento DET
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Context of the research activity	This PhD challenges the unsustainable trend of monolithic AI for generalist robots. It proposes a new paradigm: distributed "collective robotic intelligence." The research will develop frameworks for specialized robot teams to learn, interact, and collaborate, achieving superlinear gains in scalability, adaptability, and complex skill acquisition for real-world applications.
Objectives	This PhD programme confronts a critical bottleneck in modern robotics: the reliance on large, monolithic AI models to create solitary, generalist robots. This approach is computationally unsustainable and fails in the inherently interactive real world. Inspired by philosophical "extended mind" theory and natural collective systems, this research proposes a fundamental paradigm shift towards distributed "collective robotic intelligence." The core thesis is that intelligence in robotics should not be encapsulated within a single agent but should emerge from the interactions of a team of specialised, interdependent robots. This "mixture-of-robots" approach promises superlinear performance gains, superior resilience, and the ability to learn social skills like theory of mind that are impossible for isolated agents. The research agenda is structured around key open challenges identified in the literature: 1. Dynamic Compositionality: Developing algorithms for the real-time assembly and disassembly of specialised robot skills to solve novel tasks, moving beyond static model architectures. 2. Emergent Communication: Investigating methods for robots to automatically synthesize and negotiate communication protocols, deciding what, when, and with whom to share information to achieve shared goals.

	3. Collective Metrics & Learning Objectives: Designing new performance benchmarks and reward structures that incentivize collaboration, shared intentionality, and team-level resilience, rather than just individual success. 4. Robustness in Heterogeneous Systems: Ensuring the security and reliability of robot collectives against failures, adversarial attacks, and misaligned behaviours propagated through interaction. This programme sits at the intersection of robotics, multi-agent systems, embodied AI, and machine learning. The candidate will employ techniques from dynamical systems, consensus, reinforcement learning, graph neural networks, and curriculum learning, validated through simulation and real-world robotic platforms. The outcome will be a novel framework for designing scalable, adaptive, and truly collaborative robot teams, with transformative potential for applications from disaster response to advanced manufacturing.

Skills and competencies for the development of the activity	The following skills, although not mandatory, constitute a plus: - knowledge of autonomous systems and/or robotics - basic of networking/IoT - coding skills (C++, ROS, Python. Matlab/Simulink) - foundations of machine learning