POLITECNICO DI MILANO

PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 40th cycle

Research Area n. 1 - Computer Science and Engineering

PNRR 630 Research Field: DEVELOPMENT OF REINFORCEMENT LEARNING ALGORITHMS FOR INDUSTRIAL APPLICATIONS

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The advent of Industry 4.0 underscores the critical need for intelligent systems to enhance productivity and operational efficiency. Reinforcement Learning (RL) offers promising solutions to complex industrial problems by enabling systems to learn optimal behaviors through experience. Despite its potential, applying RL in industrialsettings poses unique challenges, including safety constraints, high-dimensional state spaces, and the necessity forreal-time decision-making. This research is driven by the need to bridge the gap between theoretical RL advancements and their practical implementation in industry, fostering innovation and competitiveness. The primary goal of this research is to develop and validate RL algorithms specifically designed for industrial applications. The research will focus on designing algorithms that efficiently handle high-dimensional state and actions paces, ensuring they are robust and capable of real-time operation. Safety mechanisms will be integrated to complywith industrial safety standards. To test and validate these algorithms, simulations that accurately mimic real-world industrial processes will be developed. Performance benchmarking against existing methods will provide insights into their effectiveness and areas for improvement. Collaboration with industry partners will help identify key

	application areas, such as robotic assembly and process optimization. Prototype systems will be developed and tested in real-world industrial settings to assess their practical effectiveness and scalability. To ensure the developed RL algorithms can generalize across different industrial processes, the research will explore transfer learning techniques. These techniques enable the transfer of learned policies from simulations to real-world applications, thus reducing the need for extensive retraining. Dissemination of research findings through publications in high-impact journals and conferences will contribute to the broader scientific and industrial communities. Engagement with industry stakeholders through workshops and seminars will promote the adoption of RL technologies in industrial applications.
Methods and techniques that will be developed and used to carry out the research	The research will employ a combination of advanced methods and innovative techniques to develop and validate reinforcement learning (RL) algorithms tailored for industrial applications. Initially, state-of-the-art RL frameworks,such as deep Q-networks (DQN) and proximal policy optimization (PPO), will be enhanced to handle the high-dimensional state and action spaces prevalent in industrial settings. Safety-aware RL methods will be incorporated to ensure adherence to industrial safety standards. High-fidelity simulation environments replicating real-world industrialprocesses will be developed using tools like Gazebo and OpenAI Gym, allowing for extensive algorithm testing and validation. Transfer learning techniques will be utilized to transition the learned policies from simulations to real-worldapplications, minimizing retraining efforts. Additionally, domain adaptation methods will be explored to ensure algorithm robustness across varying industrial scenarios. Collaboration with industry partners will facilitate real-world trials, providing critical feedback for iterative improvement. The research will also leverage machine learning libraries such as TensorFlow and PyTorch for efficient implementation and scalability of the developed RL algorithms. Through these methods and techniques, the research aims to achieve practical and

	impactful advancements in industrial RL applications.
Educational objectives	During the PhD, the candidate will develop advanced knowledge and skills in reinforcement learning (RL) for industrial applications. The candidate will gain a deep understanding of RL algorithms and their practical deployment in high-dimensional, real-world industrial contexts. The research emphasizes the development of novel RL algorithms, integrating safety mechanisms to meet industrial standards. The candidate will master creating and using simulation environments for testing and validating these algorithms, as well as deploying them in real-world settings throughindustry collaborations. The curriculum will cover transfer learning techniques to transition policies from simulations to practical applications,ensuring algorithm robustness across various industrial scenarios. Additionally, the student will enhance their research skills in experimental design, data analysis, and scholarly communication, preparing them to publish in high-impact journals and present at conferences. The program also fosters interdisciplinary collaboration and networking with industry experts, ensuring students can effectively drive innovation in RL applications. Finally, the candidate will learn to consider the ethical implications and societal impacts of their work, ensuring that their developments in AI and RL are both effective and responsible.
Job opportunities	Graduates of this PhD research program in reinforcement learning (RL) for industrial applications will be well-positioned for a range of high-demand career opportunities. Industries such as manufacturing, robotics, autonomous systems, and logistics increasingly seek professionals with expertise in advanced AI technologies like RL to optimizeprocesses, improve efficiency, and reduce operational costs. Job roles may include RL algorithm developer, AI research scientist, machine learning engineer, or data scientist specializing in industrial automation. Additionally, graduates may find roles in research institutions or academia, contributing to the ongoing advancement of RL theory and its application in industrial settings. The interdisciplinary nature of the

	program equips graduates to navigate diverse career paths, from technical roles in algorithm development to leadership positions overseeing AI-driven initiatives within organizations. Overall, the PhD program prepares graduates to excel in a rapidly growing field where innovation and expertise in RL are highly valued.
Composition of the research group	5 Full Professors 5 Associated Professors 14 Assistant Professors 50 PhD Students
Name of the research directors	Marcello Restelli

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	ML Cube (Milano)
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Universitat Innsbruck
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

EDUCATIONAL ACTIVITIES (purchase of study books and material, including computers, funding for participation in courses, summer schools, workshops and conferences): financial aid per PhD student.

TEACHING ASSISTANTSHIP: availability of funding in recognition of supporting teaching activities by the PhD student. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

COMPUTER AVAILABILITY:
1st year: Yes
2nd year: Yes
3rd year: Yes