POLITECNICO DI MILANO

PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 39th cycle

Research Area n. 3 - Systems and Control

PNRR 117 Research Field: DATA-DRIVEN, LEARNING-BASED APPROACHES FOR VIRTUAL SENSING AND CLOSED-LOOP REGULATION OF LASER WELDING FOR SMART MANUFACTURING

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 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 growing adoption of robotic laser welding processes, alongside the more traditional transferred arc ones, requires the implementation of technical solutions that guarantee high process flexibility and quality. Among these, an industrially recognized solution is that of Dynamic Beam Shaping through the formation of an apparent thermal beam, obtained with "wobbling" type laser beam focusing heads. Wobbling technologies offer two main advantages on the final quality of the welded product: 1. They ensure process robustness when welding high-reflection materials (aluminum alloys); 2. They allow high flexibility of the processes through the creation of apparent thermal beams of variable size and shape, making the process adaptable to significant variations in the coupling conditions of the joints to be welded. Wobbling technology also makes it possible to improve the technological solutions that are ancillary to the welding process and guarantee an increase in the quality of the welding process itself. An example is given by the possibility of using the laser beam deflection and control for: - ensuring tracking in real time of the correct position of

	the welded joint; - providing adaptation of the characteristics of the apparent beam (oscillation frequency, oscillation amplitude, shape of the oscillation trajectory) while the real morphology of the joint to be welded varies, for example in the presence of a (variable) gap between the edges to be joined. Last but not least, the presence of a controller dedicated to the wobbling system, often equipped with control outputs that can regulate other devices of the welding system (for example the laser source, or the accessory for feeding the filler wire) has the potential to increase the flexibility and control opportunities of the laser welding process. This research aims to devise learning-based data-driven techniques for both modelling the laser welding process, estimate the actual welding trajectory to be followed in real time and estimate the potential gap that exists between the edges of the joints, which can of course vary dynamically during the welding. Furthermore, we aim at defining quantitative quality indicators to consistently evaluate the system performance and the benefits that it brings to the final product and to the welding process. This will be done thanks to active welding regulation, where the trajectory is estimated based on the images collected by cameras that directly look at the process, creating virtual sensors for control systems that regulate quality and productivity in real time. The overall system will be developed with attention to its practical applications; therefore, robustness issues will be considered, with respect to different materials and different thicknesses of the joints to be welded, as well as to the potential need of re-tuning strategies to adapt the performance to usage and components' degradation.
Methods and techniques that will be developed and used to carry out the research	As is clear from the above discussion, the design of effective smart laser welding processes requires a multidisciplinary approach, as only a context-informed design of advanced learning-based estimation and control methods can enable the desired results. Thus, the research will aim to devise machine learning

	approaches that will inform the data-analysis with process-based insights, to make the machine learning (ML) results explainable and interpretable, enabling links with the domain experts and strong cross-fertilization of knowledge.
Educational objectives	The candidate will have a unique opportunity of working in a multidisciplinary team, made by experts of control theory, machine learning and process technologies and applications, needed to address the challenging and timely research topic presented above. This entails a growth path for the candidate that will make her/him acquire different competencies – mainly technical and technological in the disciplines mentioned in the methodology description, but also considering the industrial nature of the considered problem, which is key to designing effective and practical solutions. The research outputs will target publishing on international conferences and journals, with specific attention to all the venues of interest for the different facets of the research.
Job opportunities	Expertise in data analysis, machine-learning and advanced control architectures certainly makes the PhD candidate very appealing for a wide range of high-end positions. These range from the more data-science oriented, to those more related to the industrial field of application. Thus, our Ph.D.s might apply for positions in private companies, public or private research centers or in academia.
Composition of the research group	2 Full Professors 3 Associated Professors 44 Assistant Professors 30 PhD Students
Name of the research directors	Mara Tanelli

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	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	BLM S.P.A.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Technical University of Eindhoven
By number of months abroad	6

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

The research advisor, Prof. Mara Tanelli is part of the MoVE group: https://www.move.deib.polimi.it/;
The research will be co-directed by Prof. Barbara Previtali, Dept. of Mechanical Engineering

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: individual use.

DESK AVAILABILITY: individual use