POLITECNICO DI MILANO

PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 38th cycle

Research Area n. 3 - Systems and Control

PNRR_352 Research Field: VISION-BASED SMART LASER MANUFACTURING VIA ADVANCED MACHINE LEARNING AND CONTROL APPROACHES

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	Laser machining is a highly flexible non-contact fabrication method used for an increasing number of applications, and applied to the processing of an extensive range of materials in almost all manufacturing industries. However, the flexibility inherent in the process, e.g., the large number of different wavelengths, pulse energies and pulse lengths makes process optimization challenging. Even when the optimal parameters have been determined, small changes during manufacturing, e.g., in laser power or beam shape, or variations in the operating conditions (e.g., spread in the material characteristics) can result in a final product quality that is below the required standard, with associated cost and waste. What is needed to make laser manufacturing smart and sustainable, therefore, is a set of defect modelling, real-time quality evaluation and performance control methodologies that can identify the process optimal parameters and provide real-time monitoring and control-regulated quality levels. However, the highly non-linear light¿matter interactions make the physics behind laser machining particularly complex, so that physic-based models can hardly be built with the desired precision. On the other hand, data-driven and learning-based approaches offer a promising way to build advanced software-sensing schemes and control architectures that

	can optimize productivity in real-time and achieve both cost and waste reductions. This research aims to devise learning-based data-driven techniques for modelling laser machining processes and define quantitative quality indicators to optimize productivity in real-time. This will be done thanks to active quality regulation, where cutting defects are estimated based on the images collected by cameras that directly look at the cutting process, creating virtual sensors for control systems that regulate quality and productivity in real time. Further, vision will be also exploited to monitor the full machine space, in order to combine both scenarios and maximize the information on quality of cutting and health and usage status of the machine. The overall system will be developed with attention to its practical applications; therefore, robustness issues will be considered, with respect to different cutting geometries and machine installations and to the possible needs of re-tuning strategies to adapt the system 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 manufacturing 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. In particular, vision-based software sensing approaches will be developed, tailored to both regression (i.e., the estimation of a continuous variable) and classification of

	events (i.e, either binary or categorical variables), for which dedicated methods will be considered. As for control design, both model-based and data-driven approaches will be considered, in order to establish advantages and disadvantages of both approaches in the different applications that will be addressed.
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, 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 focused on the industrial nature of the considered problem, which is key to designing effective and pratical 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 control theory, data analysis, machine-learning and computer vision will certainly make the Ph.D. graduate very appealing for a wide range of high-end positions. These span from the more scientific and data-science oriented, to those more related to the industrial field of application. Thus, our graduates 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 2 Assistant Professors 20 PhD Students
Name of the research directors	Prof. 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)	ADIGE S.P.A., gruppo BLM (https://www.blmgroup.com/it/)
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Fraunhofer Institute for Material and Beam Technology IWS ¿ Dresden (https://www.futuream.fraunhofer.de/en/partners/Fraunhofer_IWS.html)
By number of months abroad	6

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

Attinenza alla tematiche, alle missioni/componenti prescelte del bando PNRR v. D.M. 352, art.6

L'attività di ricerca si colloca nell'ambito della missione M1C2 - Digitalizzazione, innovazione e competitività nel sistema produttivo del PNRR, con particolare riguardo all'azione finalizzata agli incentivi per la transizione digitale e per l'adozione di tecnologie innovative e le competenze digitali da parte del settore privato. Le attività previste da questo dottorato, in particolare, si concentrano sull'adozione di nuove tecnologie nel settore manifatturiero del taglio laser di precisione. In particolare, si intende impiegate tecniche di controllo attivo del processo di taglio, rese possibili dalla stima in tempo reale dei difetti del taglio realizzati mediante l'impiego di immagini del processo stesso opportunamente elaborate, che consentano una ottimizzazione della produttività ed un monitoraggio in tempo reale della macchina che consente strategie di manutenzione predittiva che ne estendono la vita utile e ne migliorano le prestazioni.

Impresa, presso cui si svolgerà l'attività esterna

Nome impresa: ADIGE S.P.A., gruppo BLM
Settore attivita': manifatturiero
descrizione sintetica attività: Le attività previste da questo dottorato si concentrano sullo sviluppo di tecniche di controllo attivo del processo di taglio, rese possibili dalla stima in tempo reale dei difetti del taglio realizzati mediante l'impiego di immagini del processo stesso opportunamente elaborate, che consentano una ottimizzazione della produttività ed un monitoraggio in tempo reale della macchina che consente strategie di manutenzione predittiva che ne estendono la vita utile e ne migliorano le prestazioni.

eventuali collaborazioni pregresse: Attivo JRC di Ateneo, di cui la responsabile scientifica della borsa è membro del comitato di gestione. E' attualmente attivo un contratto biennale su temi in linea con quelli della borsa di dottorato.

Impresa, presso cui si svolgerà l'attività esterna

Nome ente: Fraunhofer Institute for Material and Beam Technology IWS Dresden.
Settore: centro di ricerca
descrizione sintetica attività: Durante il periodo press il centro si intende validare la stima dei difetti del taglio con gli esperti di processo locali, e apporfondire le tematiche tecnologiche ad essi legate.
eventuali collaborazioni pregresse: L'istituto ha già ospitato in passato un dottorando (ora dipendente dell'azienda) durante in period di dottorato per attività congiunte sempre in tema taglio laser.

All information regarding educational activities, personal funding, regulations and obligations of Ph.D. candidates are available on the web site https://dottoratoit.deib.polimi.it/