## DIPARTIMENTO DI INGEGNERIA – UNIVERSITY OF PERUGIA PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING – 41st CYCLE

Title of the research activity:	Artificial Intelligence in smart additive manufacturing machines
	Development and integration of novel artificial intelligence (AI) technologies to promote self-awareness, in-process monitoring and control in additive manufacturing machines.
State of the Art:	The introduction of advanced manufacturing in Industry 4.0 and 5.0 drives the need to investigate solutions specifically dedicated to automating the machine capabilities for in-process monitoring, control and adaptive optimisation. The most recent developments in the field of artificial general intelligence (AGI) deep learning, generative AI and large language models (LLMs), combined with multi-sensing and machine vision, suggest promising avenues of investigation converging into new types of machine intelligence, applicable to the next-generation of industrial robots and CNC manufacturing machines, touching concepts such as machine self-awareness, artificial memory and learning-by-doing of autonomous agents. Particularly interesting is the investigation of the above themes in the context of additive manufacturing processes, which are in parallel revolutionising several industrial sectors, for example aerospace (realisation of lightweight aerospace structures) and biomedical (regenerative medicine, bio-engineered devices).
Short description and	The research project will be carried out in the Smart Manufacturing
objectives of the research activity:	Laboratory, at the Department of Engineering, under the supervision of the Manufacturing and Automation research groups. The project will adopt a multi-disciplinary approach to investigate the development of on- machine AGI, combining i) multi-sensing (including computer vision and 3D vision by optical and non-optical measurement), ii) advanced model- based and model-free control technologies, iii) a wide range of machine learning and statistical modelling technologies (e.g., autoregressive models, reinforcement learning, generative AI, self-explaining AI and LLMs) and iv) knowledge representation approaches (e.g. ontologies), to investigate the generation of task-specific intelligent functionality in machines, concentrating in particular on in-process monitoring and control, adaptive optimisation, and autonomous learning. The focus will be on specific class of additive manufacturing processes, namely material extrusion of polymers and composites, in the context of applications in the aerospace and biomedical/bioengineering domain. The developed technologies will be tested and validated on in-house developed machine prototypes.
Bibliography:	<ol> <li>Rossi, A., Moretti, M., Fravolini, M.L. and Senin, N., 2025. Autonomous learning of digital twins for intelligent extrusion optimisation in MEX. <i>Journal of Manufacturing Processes</i>, 143, pp.321-334.</li> <li>Rossi, A., Moretti, M. and Senin, N., 2023. Pre-process Optimisation of Filament Feed Rate in Fused Filament Fabrication by Using Digital Twins and Machine Learning. In <i>Selected Topics</i> <i>in Manufacturing: Emerging Trends from the Perspective of</i> <i>AITeM's Young Researchers</i> (pp. 71-87). Cham: Springer Nature Switzerland.</li> <li>Rossi, A., Moretti, M. and Senin, N., 2022. Neural networks and NARXs to replicate extrusion simulation in digital twins for fused filament fabrication. <i>Journal of Manufacturing Processes</i>, 84, pp.64-76.</li> </ol>

	<ol> <li>Rossi, A., Moretti, M. and Senin, N., 2021. Layer inspection via digital imaging and machine learning for in-process monitoring of fused filament fabrication. <i>Journal of Manufacturing Processes</i>, <i>70</i>, pp.438-451.</li> <li>Moretti, M., Rossi, A. and Senin, N., 2021. In-process simulation of the extrusion to support optimisation and real-time monitoring in fused filament fabrication. <i>Additive Manufacturing</i>, <i>38</i>, p.101817.</li> <li>Moretti, M., Bianchi, F. and Senin, N., 2020. Towards the development of a smart fused filament fabrication system using multi-sensor data fusion for in-process monitoring. <i>Rapid prototyping journal</i>, <i>26</i>(7), pp.1249-1261.</li> </ol>
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