Development of an intelligent framework for online inspection and control of Wire Arc Additive Manufacturing

Giulio Mattera – Advisor: Prof. Luigi Nele

Curriculum: Tecnologie e Sistemi di Produzione

Wire Arc Additive Manufacturing is a Direct Energy Deposition additive technology that uses the principle of wire welding to deposit layers of material to create a finished component. Unlike other processes, like Selective Laser Melting or Electron Beam Melting, this process is advantageous for the lowest initial cost associated with equipment and the wire raw materials, for the high deposition rate, ranging from 1 kg/h to 4 kg/h, and high part sizes, that are not limited by small working volumes of technologies such as SLM or EBM. [1]

The disadvantages that still leave many open fields of research are related to the final Net-shape components, as shown in figure 1, and difficulties in managing off-line programming in a complete automated welding framework. [2]

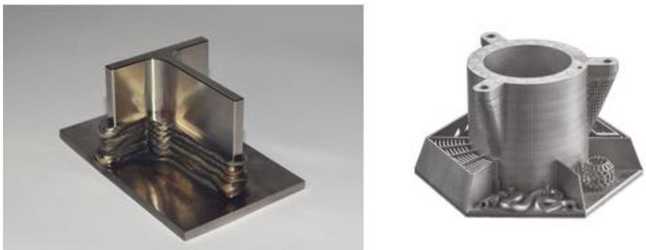

Fig 1 : Comparing an artifact in WAAM (left) and one obtained with SLM technology (right)

According to Pan et al. [3], the automated WAAM system, shown in figure 2, involves CAD modelling, 3D slicing, 2D path generation, weld setting and post-process machining, so, before obtaining the trajectory from the slicer software, the value of the bead height and width and other parameters as step-over distance have to be selected. As showed by Xiong [4] the layer bead geometry is strongly related to process parameters, which in turn are related to the presence of defects [5]. For these reasons, an intelligent framework has to be developed to correctly select and appropriately adjust the process parameters like wire feed speed, welding speed and the stick-out to obtain zero-defect components with the best surface roughness possible. Intelligent systems can reduce the removed materials during machining, saving cost in time and material waste, as defined by Buy-To-Fly ratio.

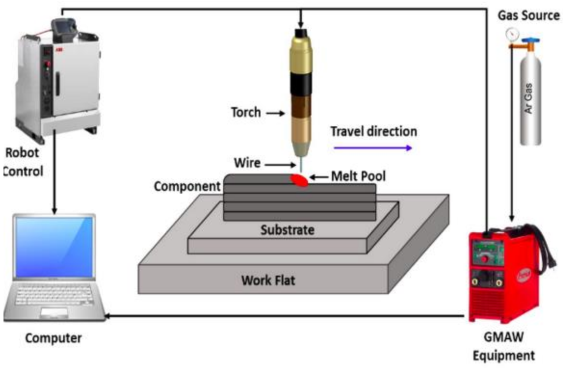

Fig 2 : Industrial WAAM components

For this purpose, artificial intelligence techniques like deep neural networks might be developed to create soft-sensor and data-driven models [4], useful to create feedback for the control system and to develop control strategies following the model-based design approach, or to create software modules for online quality inspection, as reported in figure 5 [6].

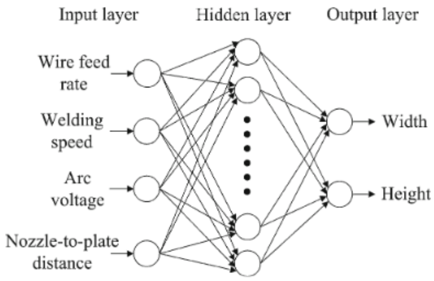

Fig 3 : Soft sensor to measure bead geometry used in [4]

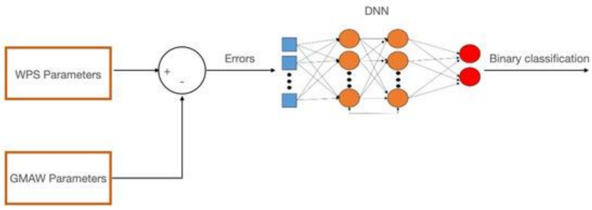

Fig 4 : AI SW module for on-line quality inspection proposed by [6]

The first results of this research have led to the development of a software module reported in [6] and to the development of a multi-physical lumped model of the WAAM process in MATLAB/Simulink environment. Acquired data from a real process will parametrize this high non-linear dynamic system, and with the developed inspection module, this model will be used to design an intelligent controller through deep reinforcement learning once an opportune reward is found.

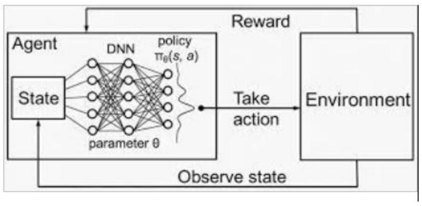

Fig 5: Deep reinforcement learning for Markovian Decision Processes (MDPs)

Finally, an automated WAAM workstation will be designed and integrated with developed and tested intelligent software modules, using the newest high-performance edge computing devices and robotic frameworks as ROS.

References

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