Metrological validation of a robotized 3D vision system for *in-situ* geometric inspection in metal additive manufacturing

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LURPA (Laboratoire Universitaire de Recherche en Production Automatisée) at ENS Paris-Saclay offers a **research internship (Master 2 level)** focused on integrating a camera on a robot for *in-situ* measurement in wire laser additive manufacturing (WLAM) and comparing it with a **fixed stereo vision system**.

Metal additive manufacturing enables the production of parts with complex geometries, opening up new opportunities for the industrialization of metallic components. However, controlling the geometry, detecting its defects, and ensuring process repeatability remain major challenges for part qualification and reliability. Defects may originate from deposition trajectories, thermal effects, or other process disturbances, making real-time inspection essential. To address these issues, **hybrid processes combining additive and subtractive manufacturing** are being developed. This hybridization offers several advantages: it allows for direct intervention during the process, enables local defect correction, provides an improved surface finish, and ensures more accurate geometric control. The combination of both processes thus paves the way toward reliable, repeatable additive manufacturing suitable for demanding industrial applications.

In this context, ***in-situ* measurement** becomes a key tool for detecting geometric defects, ensuring process stability, and supporting the development of hybrid manufacturing. The current LURPA cell is equipped with **two fixed cameras forming a classical stereo system**. Previous work *[K. Hachem, Dynamic updating of the geometric model produced in additive manufacturing by metallic wire deposition, PhD thesis, Université Paris-Saclay, October 2025]* has demonstrated the ability to perform 3D measurements of parts, including different representations of defects depending on the scale of the analysis. However, this configuration is limited by the distance between the cameras and the part, as well as by the fixed viewing angle, which can make certain areas difficult to observe and reduce measurement flexibility.

The proposed internship aims to develop a **new measurement configuration** in which a camera is mounted directly on a robot. This approach will enable the camera to be positioned closer to the part and capture dynamic images from various viewpoints during deposition, synchronized with the robot's motion and the positioner's position. The on-board camera will be calibrated using the **hand-eye calibration method**, which determines the exact geometric transformation between the robot coordinate frame and the camera frame. This calibration links camera measurements to real robot-space coordinates, enabling the accurate geometric reconstruction of the part even when the camera is in motion. The measured defects will be represented using a **modal approach based on stereo digital image correlation**. The results will be compared with those obtained from the fixed stereo configuration in order to assess the **accuracy, repeatability, and robustness** of each method. This work will provide insight into the advantages and limitations of both approaches and propose a robust methodology for ***in-situ* geometric inspection of the wire laser additive manufacturing process at LURPA**.

Keywords: metal additive manufacturing, digital image correlation, *in-situ* measurement, robotics, hand–eye calibration, geometric defects

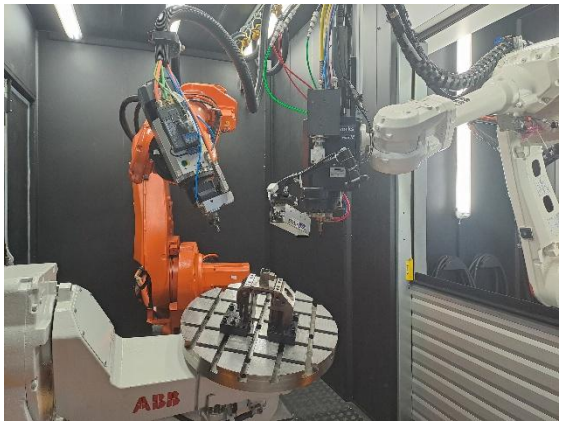

Figure 1: Hybrid wire laser metal additive manufacturing cell at LURPA

Figure 2: Example of a WLAM part measured in-situ using the fixed stereo system

Activities:

- Literature review on stereo vision and robot-based *in-situ* measurement in metal additive manufacturing;
- Design and mounting of the camera on the robot;
- Calibration and experimental validation of the robot–camera system;
- Data acquisition and processing;
- Performance comparison and analysis between the two configurations;
- Writing of the internship report.

Profile: Master's or engineering student in mechanical engineering, with strong skills in robotics and/or metrology.

Skills:

- Knowledge of robotics, computer vision, and instrumentation;
- Knowledge of camera calibration is a plus;
- Comfortable with experimental hardware;
- Autonomy, intellectual curiosity, motivation;
- Ability to communicate in French or English, both orally and in writing.

Internship location:

- LURPA ENS Paris-Saclay, 4 avenue des sciences, 91190 Gif-sur-Yvette
    - Supervisors: Khalil Hachem, Yann Quinsat, Christophe Tournier,

Duration and compensation:

- 6-month internship starting around February/March 2026
- Indicative monthly compensation: ~€670

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