Newsletter 7

Robotics and Machine Learning for Remanufacturing.

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Among other tasks, R3-Mydas is focused on embedding robotics and machine learning into remanufacturing tasks, directly addressing performance and quality improvements across the project's use cases. Two key strands of work are under development: Cognitive Robotics for battery recycling and Quality Control for the laser cladding process.

Cognitive Robotics

Following discussions among partners, SPIN provided a robotic screwdriver which was integrated into CSEM's Universal Robot arm, while AVL supplied a battery unit adapted for safe experimentation. With SPIN's low-level code examples, CSEM implemented functions enabling complete script-based control of the screwdriver.

A deep learning pipeline was developed to detect screws by first generating thousands of high-quality synthetic images in Blender, each paired with precise position labels. This synthetic dataset provided a strong foundation for model training, which was then refined using real image data captured from the use-case battery to better approximate real-world conditions. While the initial results were solid, the model occasionally produced false detections in screwless holes. To overcome this limitation, synthetic counterexamples were introduced, enabling the system to distinguish more reliably between empty holes and those containing screws.

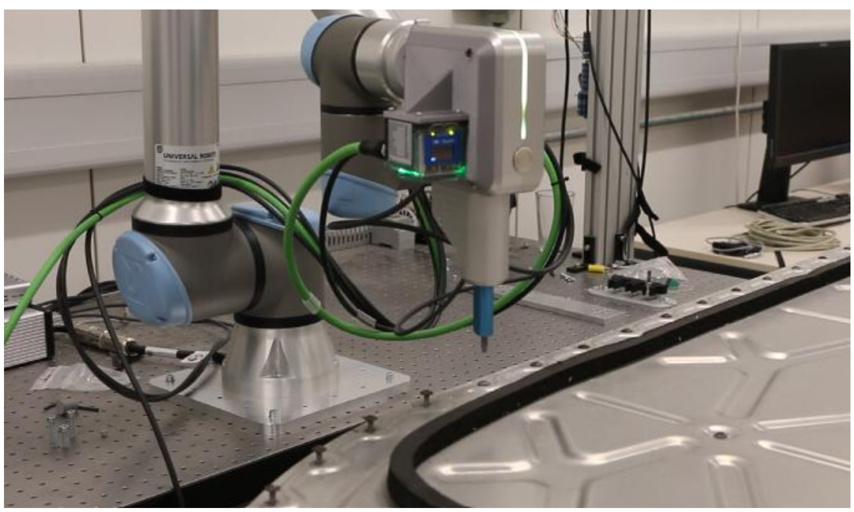

Figure 1 – Robotic unscrewing of the battery casing

The identified screws were tracked across video frames, enabling multiple points of view, which is crucial to locating them in the physical space using triangulation. Once the screw positions are known, the robot is controlled to approach them, and the screwdriver removes them one by one. Screw detection inference, triangulation and screw removal are fully integrated in an automated workflow that performs its task without human intervention.

Next steps will refine screw position estimates during approach using an adaptive strategy, which compensates for small error margins that can compromise screwdriving ability

Quality Control in Laser Cladding

In parallel, a surrogate model is being created to accelerate process optimisation for laser cladding, with future potential for closed-loop control. The surrogate focuses on mapping process parameters such as laser power and scan speed to output predicted thermal behaviour.

A neural operator approach was selected for its ability to learn mappings across a wide range of geometries and scan paths. To support this, training data was produced with CIMNE's Add2Man software, which simulates part-scale 2D laser cladding processes across diverse trajectories and process conditions. The simulation outputs were then processed through a dedicated data pipeline that structured the results into formats suitable for machine learning model training.

Several neural operator architectures were implemented, namely Fourier Neural Operators (FNO) and Convolutional Neural Operators (CNO). The trained models successfully predicted full temperature fields along unseen scan paths with high fidelity.

These results confirm the potential of neural operators as fast, accurate surrogates for thermal modelling in metal additive manufacturing.

Next steps involve extending from 2D to fully 3D modelling to bridge closer to industrial conditions, with experimental validation planned using thermal imaging data from real-world use cases.

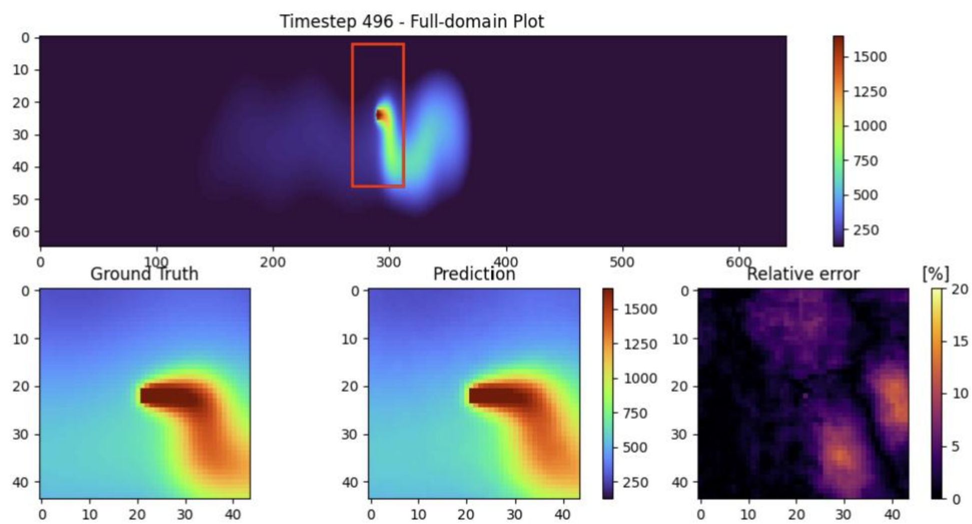

Figure 2 – Comparison of the prediction model to ground truth