VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Charles Snyers**

The public defense will take place on **Thursday 12th December 2024 at 5pm** in room **D.0.08** (Building D, VUB Main Campus)

To join the digital defense, please click here
Meeting ID: 391 433 394 175
Passcode: a8L6W5

MACHINE LEARNING-BASED PROCESS OPTIMIZATION USING HYPERSPECTRAL IMAGING IN DIRECTED ENERGY DEPOSITION

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Abstract of the PhD research

Metal Additive Manufacturing (AM) offers a design freedom that holds great potential in high-value sectors such as the aerospace and medical industries. To enable the adoption of this complex technology, there has been significant effort to overcome challenges related to reliability and quality insurance. However, the high number of process parameters, the process nonlinearities and the high-dimensionality of in-situ monitoring measurements are challenging. As a result, optimized process parameters and feedback control schemes typically work within limited operating ranges and for specific geometries.

Machine Learning (ML) algorithms have emerged as powerful data-driven methods capable of efficiently modelling non-linear relationships and handling high-dimensional inputs. However, the development of robust Machine Learning models requires substantial, labelled datasets. Efficient and quick data generation and labelling has proven to be a challenge in itself in many applications, from time-consuming hand-annotations for visual recognition datasets to expensive material testing for process datasets.

The purpose of this PhD is to address the reliability challenges of metal AM with data-driven methods to go beyond the limitations of hypothesis-driven methods. First, several substantial insitu monitoring datasets are generated both by simulation and experimentally with Directed Energy Deposition (DED), a laser and powder-based metal AM process. Practical labelling methods are presented for the DED process and used on the generated datasets.

Then, those datasets are used in conjunction with Machine Learning methods for 3 different goals:

1. Process parameter optimization: Several shallow methods are used to model the melt pool geometry and temperature from its process parameters. These models are used to locate favourable regions in the process parameter space.
2. In-situ anomaly classification: A Deep Learning model is trained to recognize and classify problematic thermal conditions from hyperspectral images of the melt pool during printing. The model capacity and its size are optimized to get the best balance between accuracy and speed. Visualization methods such as Guided GradCAM are used to gain insight in how the model classifies each melt pool image. Finally, the model is tested on a more complex geometry that was not used for its training.
3. Process feedback control: A feedback control scheme based on the in-situ anomaly classification model is used to act on the process parameters and correct the problematic thermal conditions as they are detected.