Industry Training Programme ACS6402, ACS6403 Laser Powder Bed Fusion - Process Monitoring & Defect Forecasting Technical briefing

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Mohamed Atwya[1]

[1]Department of Automatic Control and Systems Engineering
University of Sheffield

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Project Aim

From the project brief: "The task is to build a fully-validated **machine learning model** for localising porosities in **metal laser powder bed fusion** via photodiode sensory data."

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What is Additive Manufacturing (AM)

- Rapid, flexible, and cost-effective manufacturing
- Aerospace, automotive, healthcare, etc.
- Over 20 recognized AM processes with different layer sintering methods
  - Liquid-based processes (e.g., Stereolithography)
  - Solid-based processes (e.g., Fused Deposition Modeling)
  - Powder-based processes (e.g., Laser Sintering, High Speed Sintering)
- Laser powder bed fusion (L-PBF)

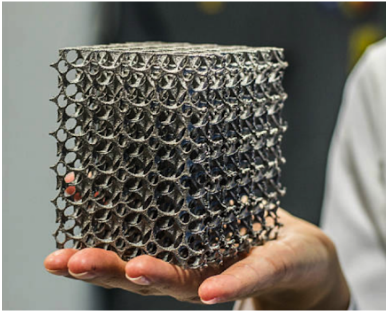

Figure: An example of metal additive manufacturing (istockphoto.com)

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Industry Partner

Advanced Manufacturing Research Centre (AMRC)

- Research and innovation centres working with advanced manufacturing companies
- Increasing productivity and competitiveness
- Developing new products and processes
- Training new talent and skills

AMRC North West, Blackburn, England

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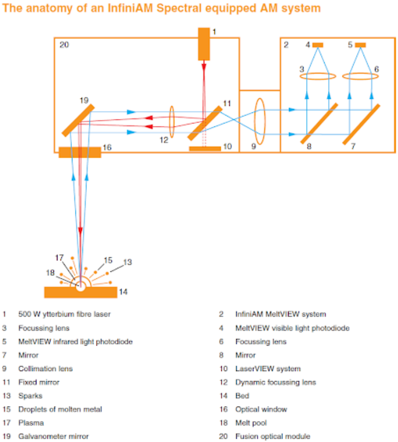
AM Process Data

(a)



(b)

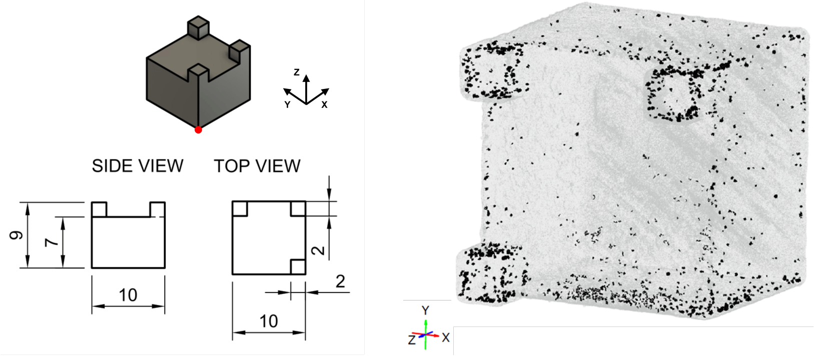
Figure: Renishaw 500M and the InfiniAM spectral emissions sensory systems - Renishaw Additive Manufacturing Systems Brochure-InfiniAM Spectral-Screen (2017), UK.

Process Data Example

Table: Example spectral emissions data from the Renishaw InfiniAM system.

Start Time	Duration (μs)	x position (mm)	y position (mm)	laserView	meltView Plasma	meltView Melt Pool
140000	30.00	55.10	10.00	600.00	300.00	100.00
140030	30.00	55.20	10.00	601.00	303.00	99.00
140060	30.00	55.20	10.00	603.00	300.00	98.00
140090	40.00	55.20	10.00	600.00	301.00	100.00
140130	30.00	55.20	10.00	599.00	302.00	100.00
140160	60.00	55.20	10.00	597.00	299.00	98.00
140220	30.00	55.20	10.00	595.00	303.00	97.00

Part Design & Porosity



(a) (b)

Figure: The part design and dimensions (mm unit) examined in this work and an example X-ray computed tomography scan.

Porosity & Sensory Data

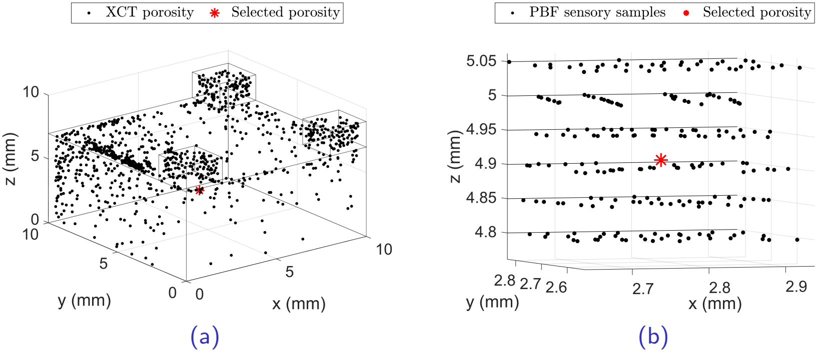


Figure: An example X-ray computed tomography scan and the coordinates of the sensory data surrounding one of the porosities.

AM Challenges

Challenges:

- Current technology tends to be open-loop
- A single AM metal part can have several microstructural features and porosity types
- Costly and time-consuming to rely on a Design of Experiment
- Numerical models in AM are accurate but computationally-expensive
- Multi-sensory data in appropriate resolution and scale to capture defects reliably

Possible Solution:

- Data-driven modelling of the process-part interaction

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Machine Learning for Porosity Detection (1)

- Create a supervised learning data set via sensory data and labels
- A supervised machine learning algorithm can predict the probability of porosity at a given three-dimensional coordinate
- For example, initialise the weights of a neural network and minimise the cross-entropy loss

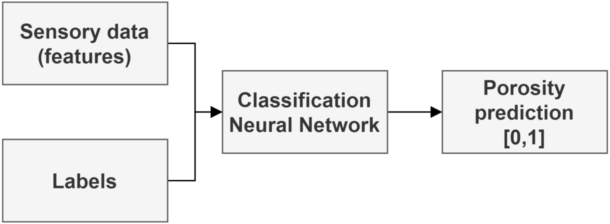

Figure: Neural network porosity classification flowchart.

Machine Learning for Porosity Detection (1)

Challenges:

- Over-fitting and under-fitting
- Unbalanced data-set
- Raw data does not capture the process-property dynamics

Possible Solutions:

- Repeated k-fold cross-validation
- Under-sampling and prior-guided neural networks
- Feature addition

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Project Objectives

- Review the literature on additive manufacturing porosity detection and localisation
- Review the industry (AMRC) data and sensing system to understand the input and target values and perform any necessary data treatment (repeated data, data imbalance, missing data, etc.)
- Identify and add features to the input data to improve the data set for a machine learning problem
- Propose a suitable method, and apply, validate, and test a supervised machine learning algorithm for localising the porosities (binary classification problem)

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Preliminary Literature Review

- Atwya, M. and Panoutsos, G., 2023. In-situ porosity prediction in metal powder bed fusion additive manufacturing using spectral emissions: a prior-guided machine learning approach. Journal of Intelligent Manufacturing, pp.1-24.
- Jayasinghe, S., Paoletti, P., Sutcliffe, C., Dardis, J., Jones, N. and Green, P.L., 2020. Automatic quality assessments of laser powder bed fusion builds from photodiode sensor measurements. Progress in Additive Manufacturing, pp.1-18.
- Liu, R., Liu, S. and Zhang, X., 2021. A physics-informed machine learning model for porosity analysis in laser powder bed fusion additive manufacturing. The International Journal of Advanced Manufacturing Technology, 113(7-8), pp.1943-1958.
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Next Steps (1)

- You are the engineering expert
- You need to decide the best approach given the circumstances
- But, you are not in industry yet, we are here to help you address the industrial challenge, and help you learn
- Two technical seminars to help you out:
  - Week 3, Data pre-processing and feature extraction
  - Week 5, Neural network classifier

Next Steps (2)

Next major project milestone:

- Deadline for interim report, Week 7

To achieve the above, you will need to

- Develop a project management plan
- Capture project requirements (systems engineering)
- Conduct a literature review, that will inform your technical plan
- Present a preliminary technical plan
- Present any preliminary technical results

Next Steps (3)

Read the handbook and have a group discussion to:

- Agree responsibilities
- Start developing a project plan
- Start putting together a list of questions for industry (to ask in Week 4). What information do you need to execute your plan?

Be clear on what actions do you need to do next, and who would be responsible for each action.

Any questions?