Image-guided Additive Manufacturing

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Industrial relevance

The proposed project will address defects, improve build quality, reduce costs, and increase the yield of additive manufacturing.

Facts:

- 🙂 *Customization* – easier to build complex, highly customized parts, add more flexibility in the design and manufacturing.
- 🙂 *Rapid growth of market* – $4 billion in 2015, $10.8 billion in 2021.
- ☹ *High rejection rate* (**>2%**) – various types of defects induced by process variations (e.g., thermal effects and extraneous noises).
- ☹ *Long post-build inspection* (**~25%** of the manufacturing time) – low yield (e.g., for engine parts) and high cost.

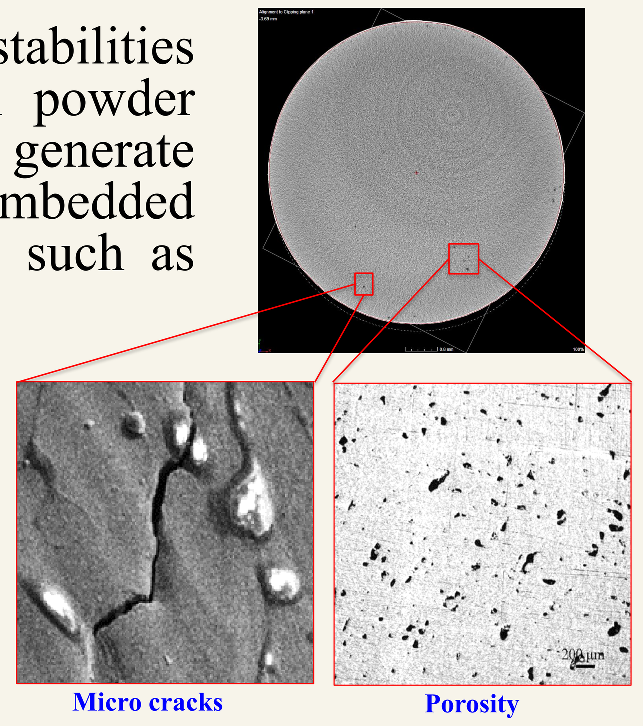
Urgent need: In-situ process monitoring and control.

Thrust area: Intelligence
Current TRL: TRL-4
Final TRL: TRL-8
Project type: Proposed project
Percent complete: 30%

Problem statement

Motivation

Process variations (e.g. laser or galvo instabilities or drift, thermal effects, variations in powder feedstock) perturb build quality and generate residual stress → the distortion or embedded flaws → impact mechanical properties such as fatigue strength.



Gaps

- Depend on post-build inspection or destructive tests.
- Lack the ability to extract pertinent information about process dynamics from images.

Need

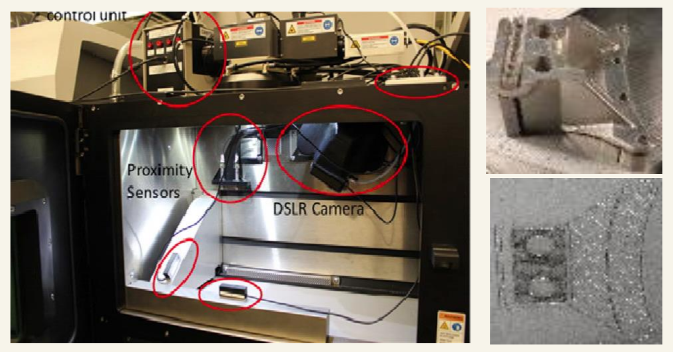
Quality control and process repeatability are critical to mass use of additive manufacturing.

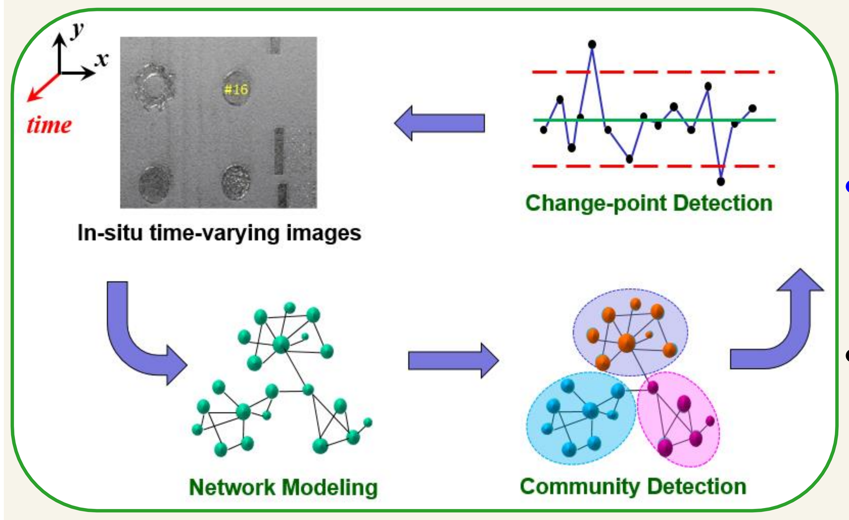
Objective

Develop an in-situ image sensing, fusion and decision-support system for real-time defect mitigation in additive manufacturing.

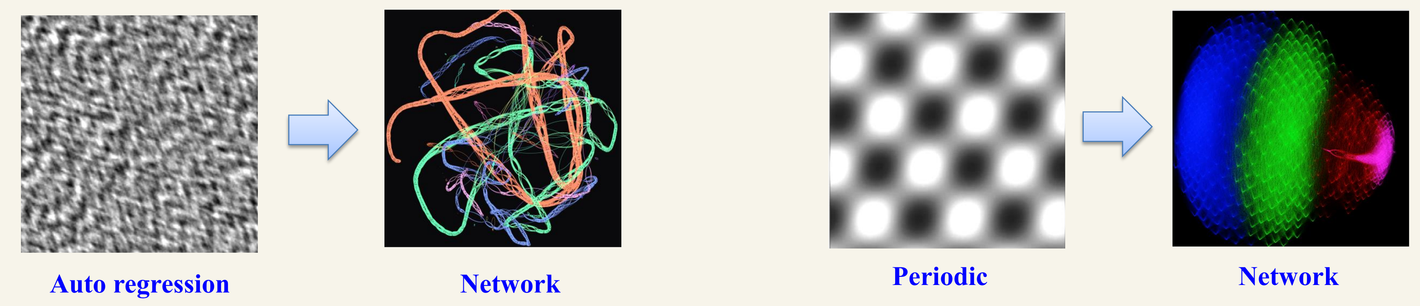
Approach and method

- In-situ image sensing (high-resolution DSLR camera, infrared thermography and CT scanner with >1000 Hz frame rate)



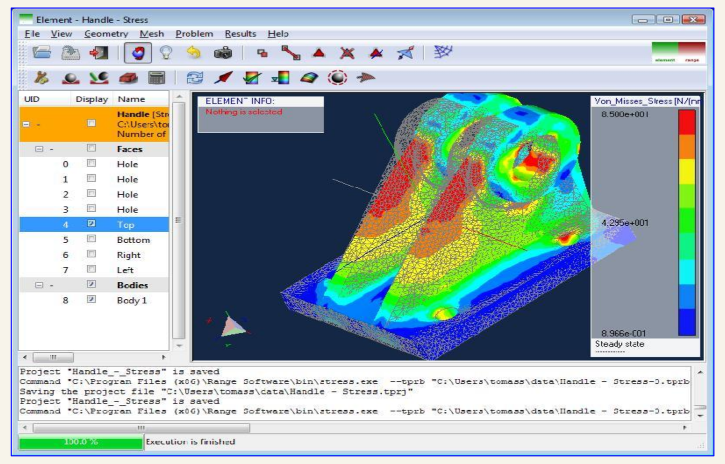


- Network GLR chart for real-time detection of defects
- Characterization of network variations → address defects



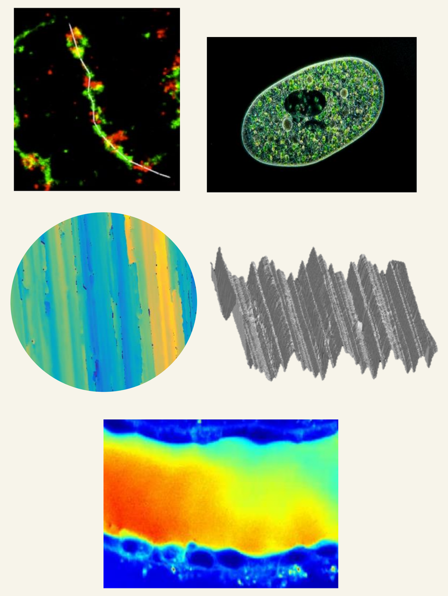
Deliverables and benefits

- An **in-situ image sensing system** that will record in-process images and CT scans of every single layer of the product while it is built.
- A **software package with graphical user interface** that will extract pertinent features about process dynamics from images for the real-time defect mitigation and optimal control.



Potential application areas

- ***Medical research*** – anomaly detection in medical images (e.g., tumor detection).
- ***Semi-conductor manufacturing*** – defect inspection in microscopic images for assessment of surface finish of wafers.
- ***Bio-manufacturing*** – change detection in cell images for in-vivo monitoring of cellular processes.



Project plan and progress

- Review current literature, data cleaning and pre-processing.
- Extract features from image data to characterize process.
- Develop data-driven models to derive quantitative relationships between image features and defect evolutions.
- Develop image-guided control policy of additive manufacturing.
- Evaluation and validation

	Month 1-2	Month 3-4	Month 5-6	Month 7-8	Month 9-10	Month 11-12	End
Literature review							
Data cleaning							
System development							
○ Image feature extraction							
○ Data-driven models							
○ Image-guided control							
Evaluation and validation							
Document and presentation							

Current state of practice and research

- Spectral band selection approach (Du *et al.* 2007) – analyze hyperspectral images of poultry carcasses.
- Low-rank tensor decomposition + multivariate control chart (Yan *et al.* 2015) – monitoring sequential flame images.
- Adaptive Gaussian process (Zhang *et al.* 2015) – characterize wafer thickness.
- Multistage semi-classification approach (Park *et al.* 2013) – characterize morphology of nanoparticles.
- Spatiotemporal control chart (Megahed *et al.* 2012) – detect non-conforming tiles.

Gap: ***Very little work has been done to develop new image-guided additive manufacturing.***

How ours is different

Our proposed approach		**Existing practices**
Just-in-time	*vs.*	Inventory
In-process control	*vs.*	Post-build inspection
High-dimensional images	*vs.*	Low-dimensional quality variables
Dynamic image streams	*vs.*	Static images

References

- Chen Kan and Hui Yang, "Dynamic network modeling of in-situ image profiles for process control – applications in ultraprecision machining and biomanufacturing processes", *submitted*, 2016.
- Chen Kan and Hui Yang, "Network models for monitoring high-dimensional image profiles", *proceeding of IEEE International Conference on Automation Science and Engineering (CASE)*, pp. 2078-2083, Aug. 24-28, 2015, Gothenburg, Sweden.