

Damage Detection for Automated Repair Systems of Metallic Components through Laser Metal Deposition

Doctorate in Mechanical Engineering

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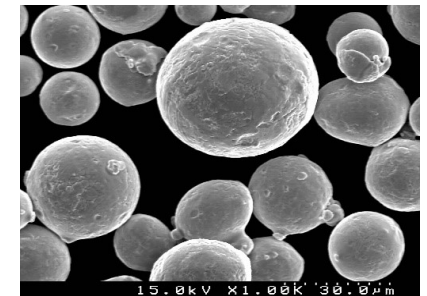
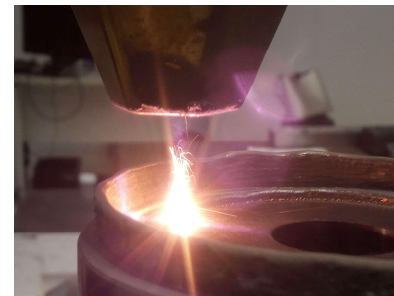
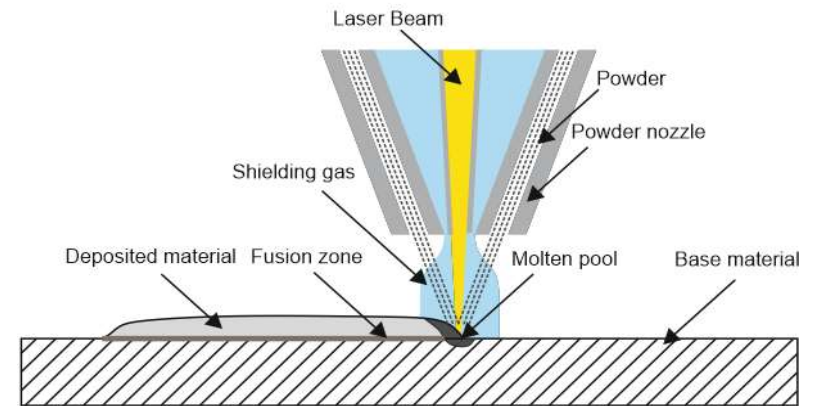


Outline

- Introduction
- Problem Statement
- Objectives
- Methods and Contributions
 - Damage Detection: Classical Geometry-Based Approach
 - Learning-Based Damage Detection from 3D Point Clouds
- Conclusions and Outlook

How does 3D printing in metal work?
What is laser metal deposition?

Laser Metal Deposition Process



Laser Metal Deposition Applications



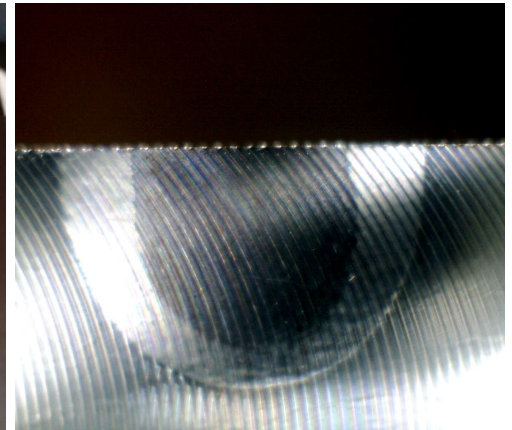
Build



Thermal Treatment

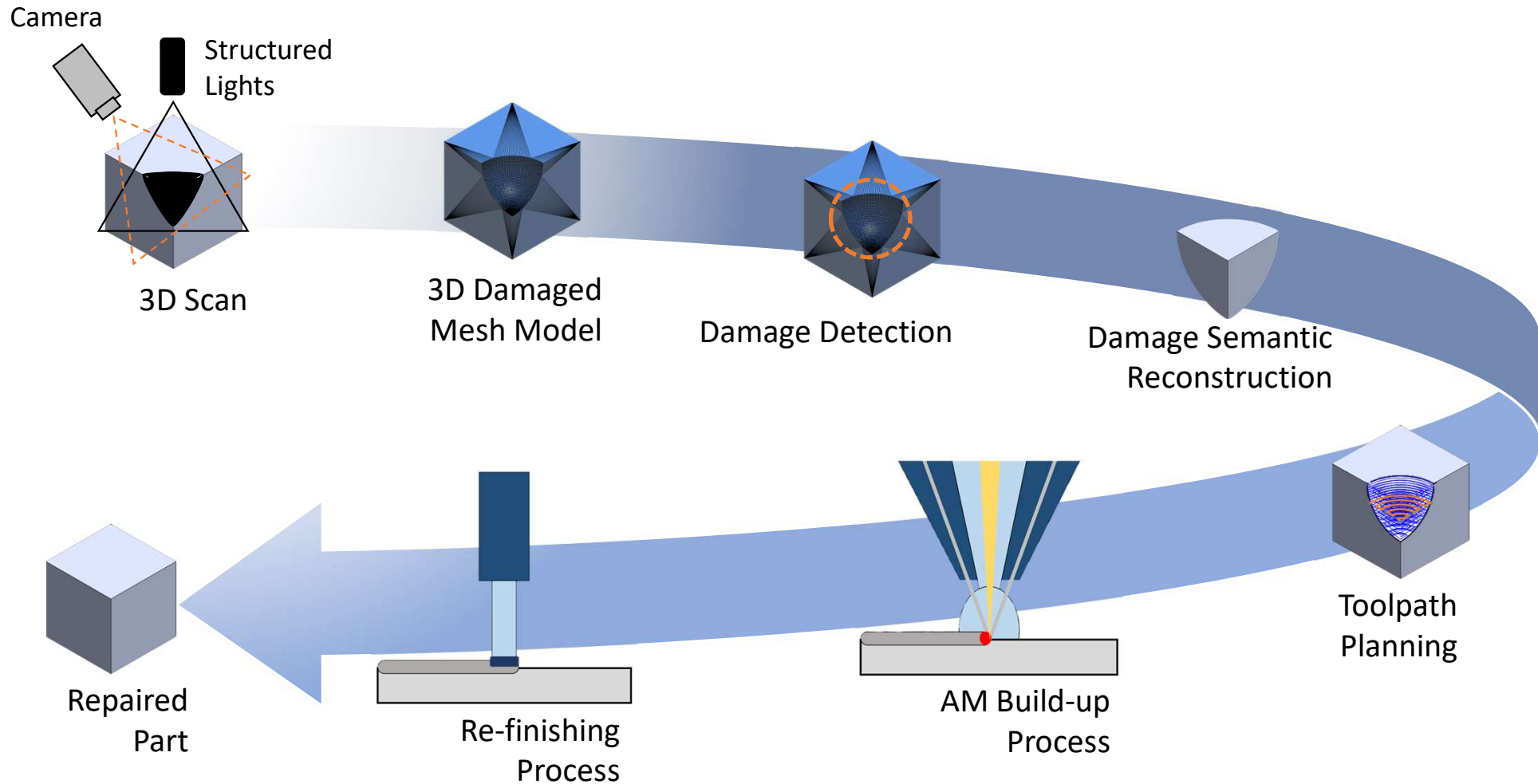


Cladding



Repair

Framework of Additive Manufacturing Repairing Process



Current Limitations in Damage Detection in Automated LMD Repair

Dependence on nominal CAD models → Poor handling of wear and deformation

Component and damage-specific solutions → Limited generalization

Predominantly 2D-based damage detection → Insufficient for complex 3D geometries

Requirements for Damage Detection in Automated LMD Repair

A repair system that:

Detects damage directly from 3D scan data without relying on a nominal CAD model

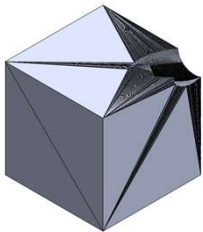
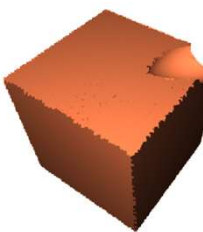
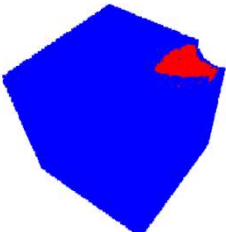
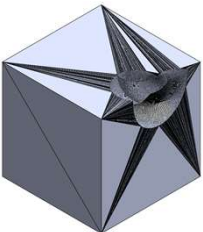
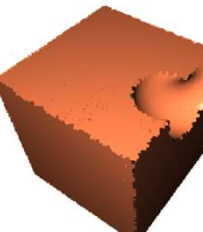
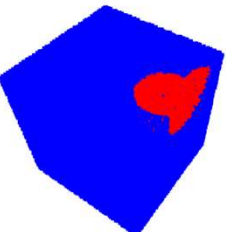
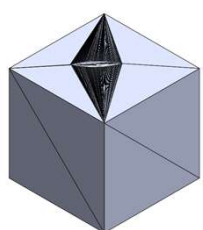
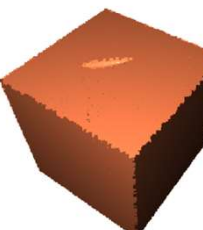
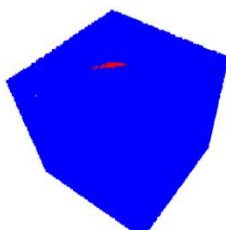
Adapts to multiple damage types, including: wear, cracks, cavities, surface loss

Is applicable to arbitrary geometries, including: planar surfaces, curved surfaces, free-form and complex geometries

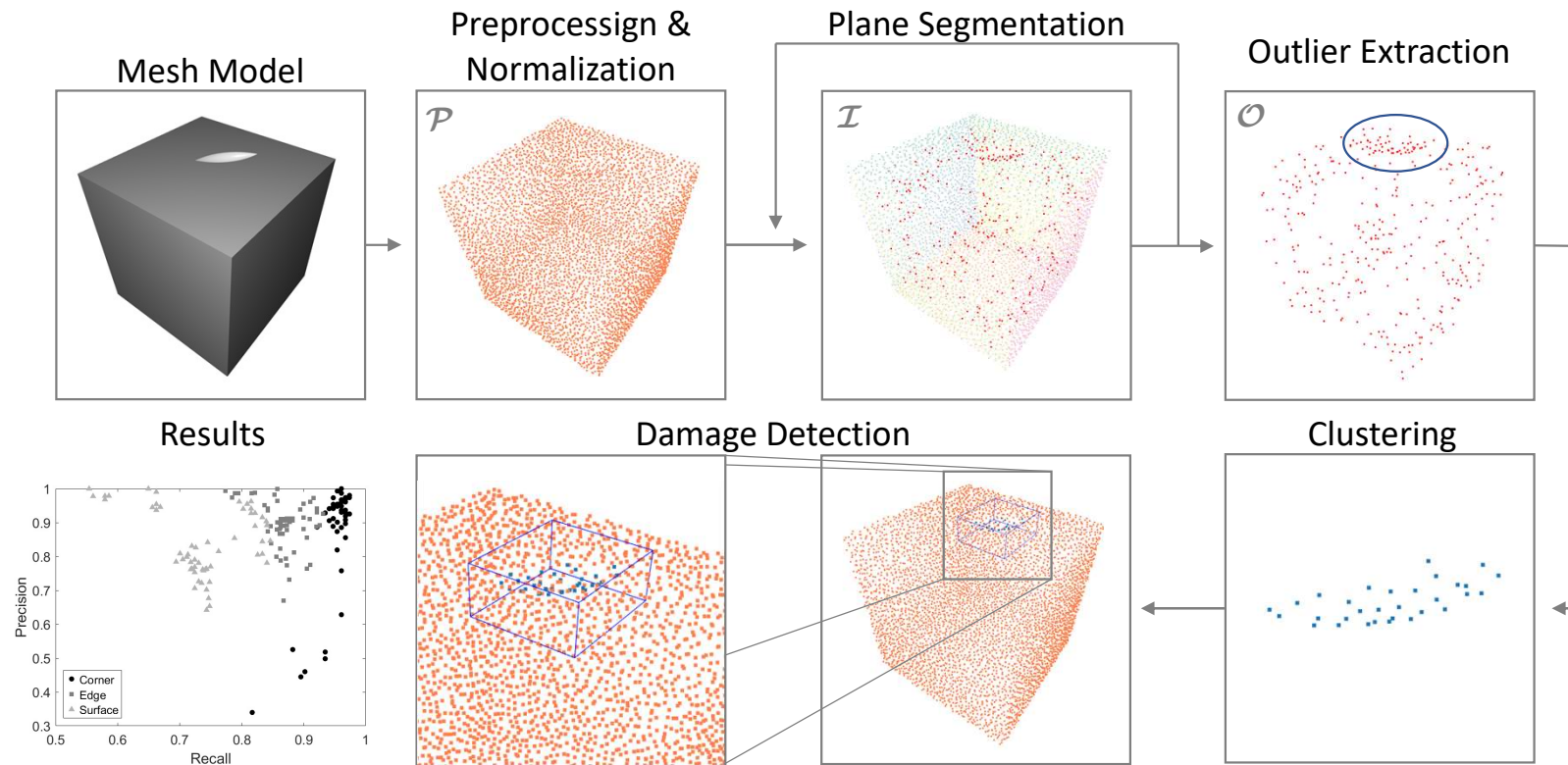
Is independent of the component type, enabling generalization across industrial parts and scalability to different applications

Methods and Contributions
Damage Detection Research Work

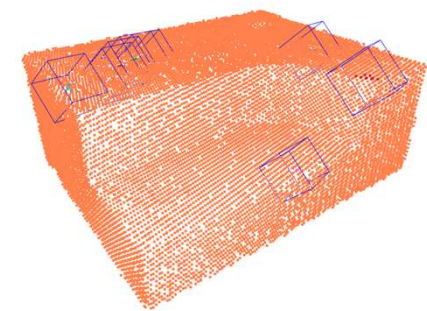
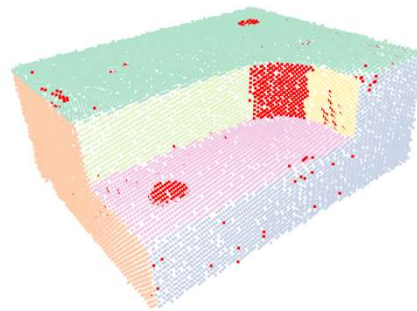
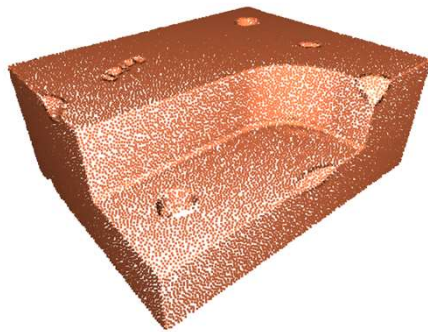
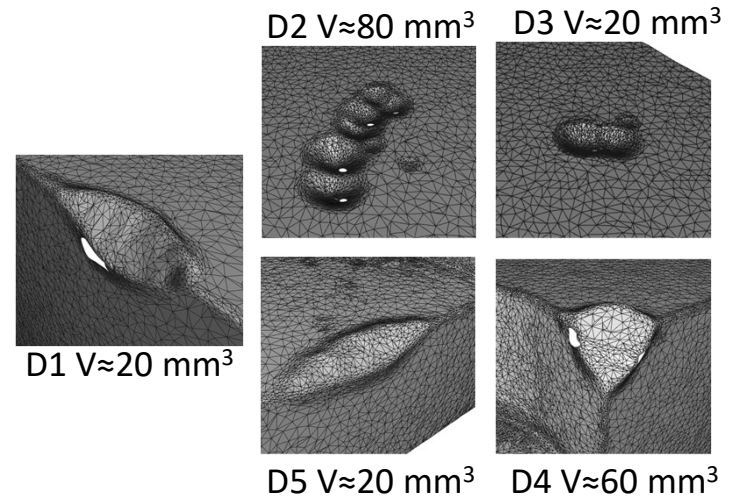
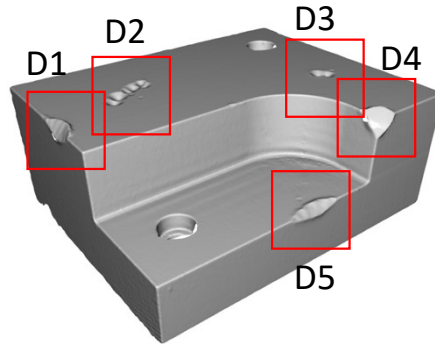
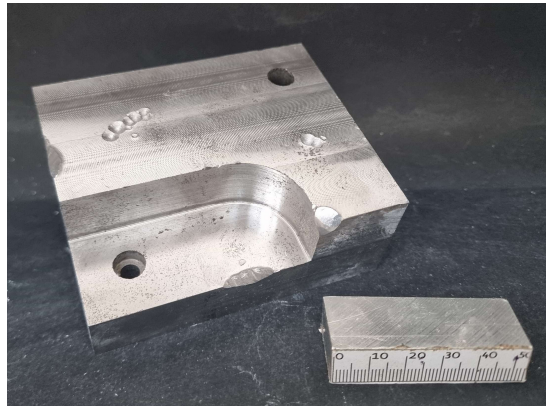
Damage Detection: Classical Geometry-Based Approach

Dataset	Mesh Model	PC Model	Ground Truth
Corner			
Edge			
Surface			

Damage Detection: Classical Geometry-Based Approach



Damage Detection: Classical Geometry-Based Approach



Motivation for Learning-Based Damage Detection

Why move beyond classical methods?

Real components are rarely planar
Damage appears in diverse shapes and scales

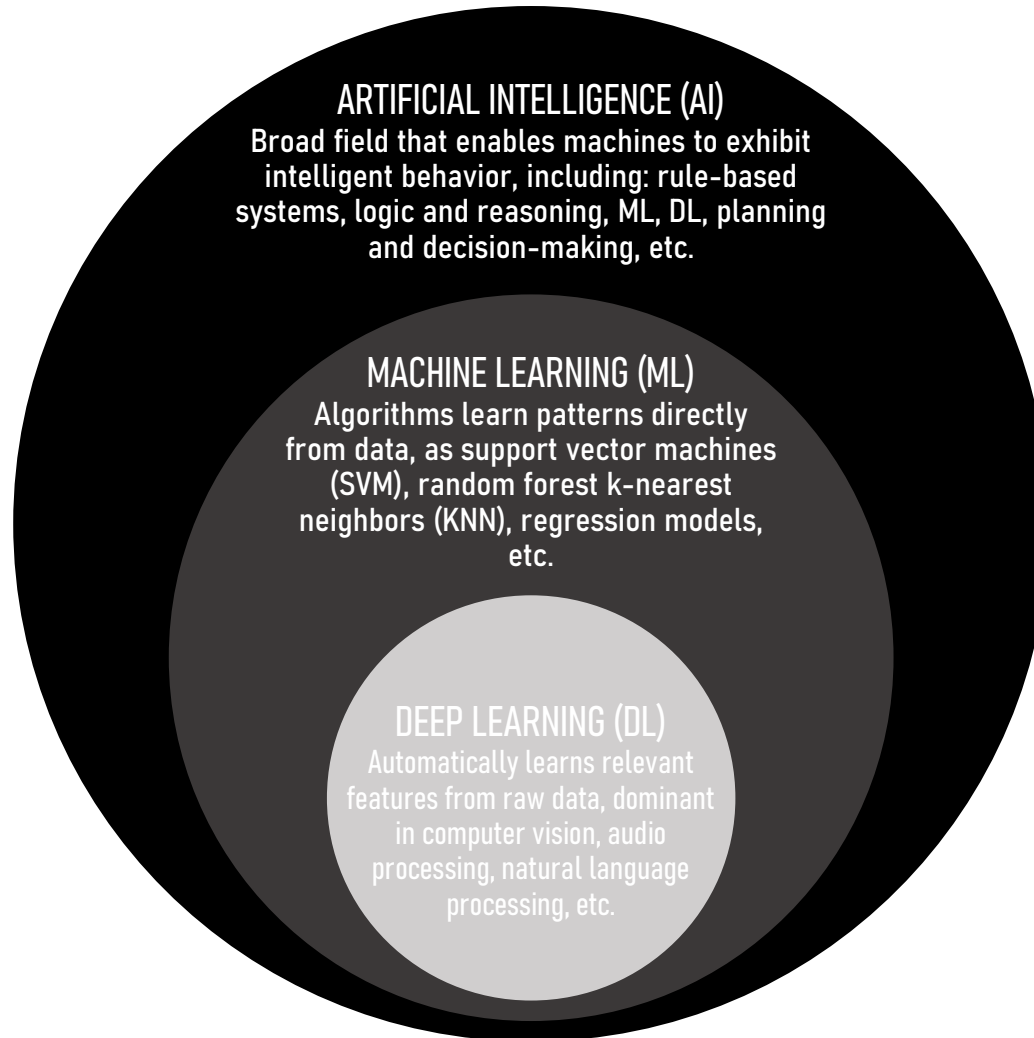
Classical methods:

Do not generalize well
Require strong geometric assumptions

Need:

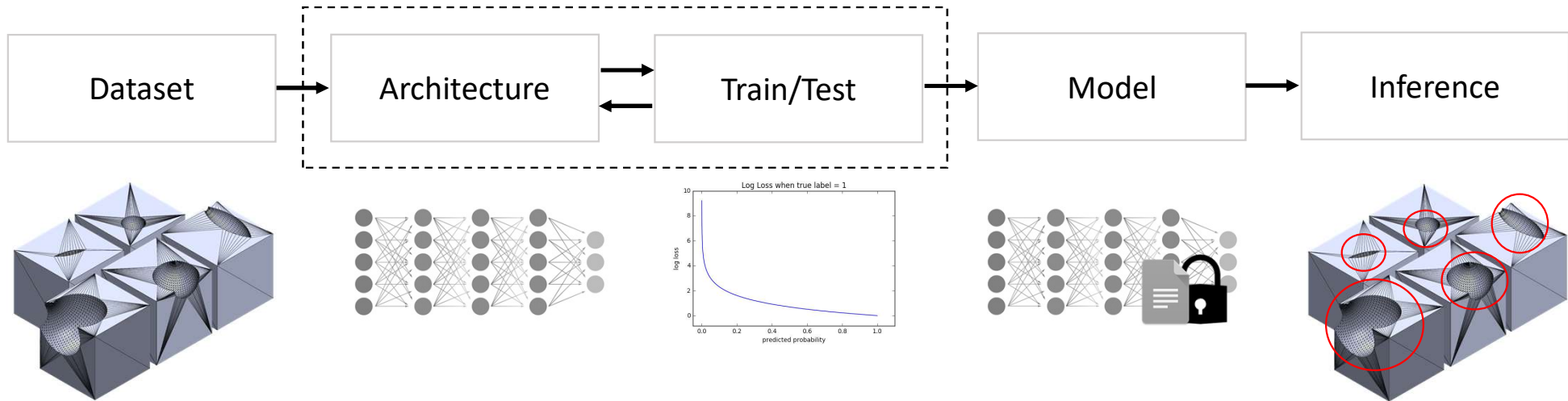
A data-driven approach

What is Deep Learning?



How it works and how to apply in damage detection?

Learning-Based Damage Detection from 3D Point Clouds



From Damage Detection to Automated Repair

Damage detection is a critical enabler for automated LMD repair

This work shows demonstrates

RAN-3D

- Model-free damage detection
- Robust across damage locations, geometries, and volumes
- Validated on real 3D-scanned components

Learning-based methods

- Better generalization
- Works on complex, non-planar geometries
- No dependence on geometric assumptions

Next steps toward full automation

Improve robustness

- Larger and more diverse datasets
- Transfer learning across components

Extend detection

- Semantic damage understanding
- Repair volume estimation

Integration

- Automated repair pipeline
- Closed-loop LMD system

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