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Part Defect Detection and Geometric Verification in Production Line Environment

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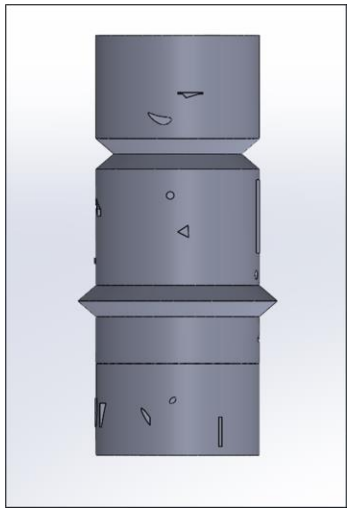
Part Defect Detection and Geometric Verification in Production Line Environment

Motivation:

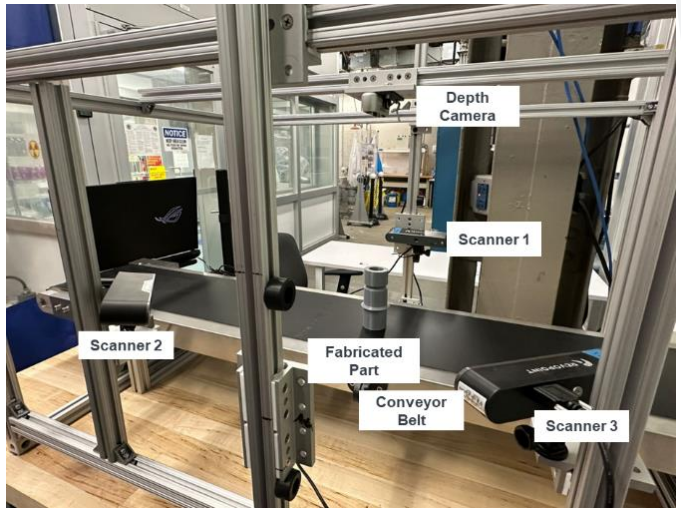
- Traditional 2D vision-based inspection systems lack depth and rely on a fixed light source, making them inconsistent.
- There is a need for automated systems that can detect defects in real time and operate independent of light conditions.

Solution Proposed:

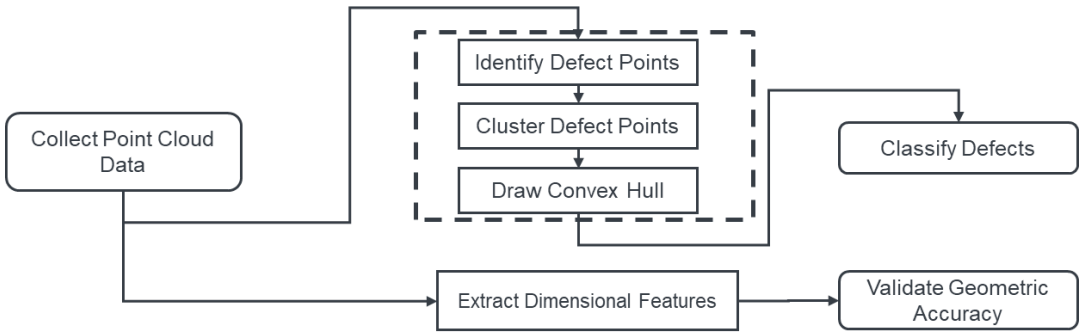
- A multi-camera inspection system for examination of fabricated parts in a prototype production line environment.
- Utilizes point cloud data to identify and classify clusters of defects.
- Uses an in-house designed and 3D-printed test specimen, fabricated using FFF(Fused Filament Fabrication) and PLA(Poly Lactic Acid) material.
- Utilizes a combination of advanced methods to identify defects and dynamically adjust process parameters of the combined algorithm, enabling autonomous defect detection and classification for any type of sample without requiring manual intervention.



Test Specimen with added defects



Experimental Setup



Inspection Process Flow

Defect detection and classification

Local Surface Variation

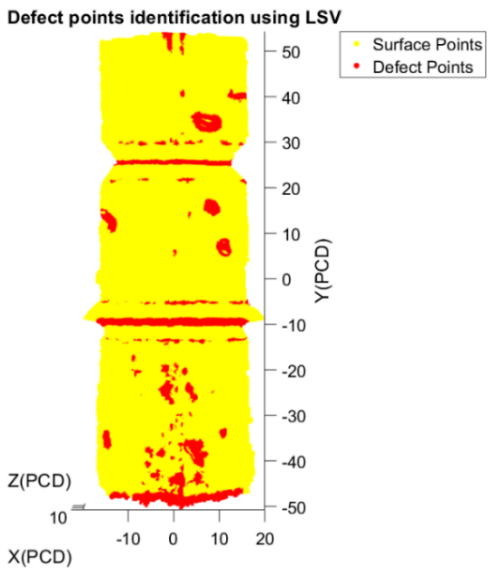
- A k-NN based algorithm that analyzes the surface variation a each point from the point cloud data.
- Implemented to identify potential defect points from the poin cloud data.
- Points in the top 90th percentile of the surface variations are marked as defective.

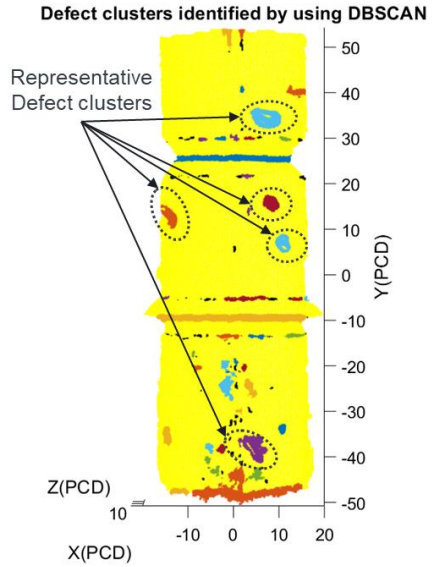
Density Based Spatial Clustering of Applications with Nois (DBSCAN)

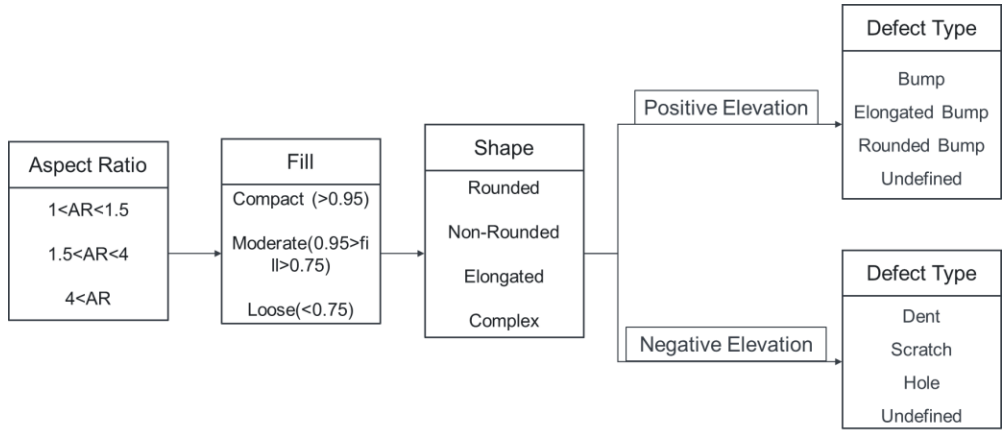
- An unsupervised clustering algorithm that groups points based on density.
- Implemented to group the marked defect points into defect clusters for further analysis.

Defect Type Classification

- Defects are classified into types based on predetermined criteria identified from the geometric features of the defect clusters.





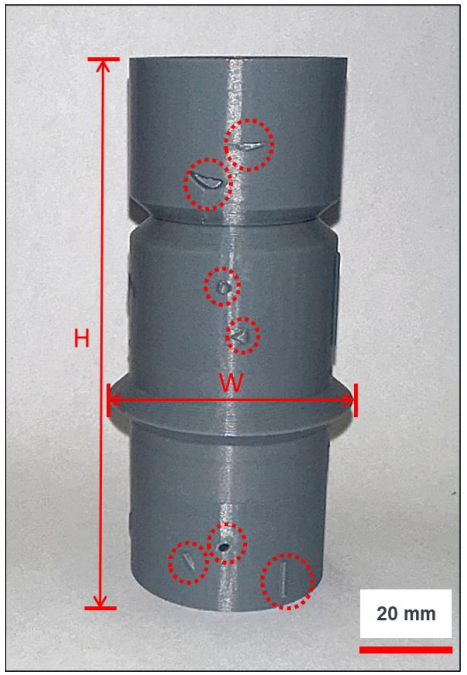


Defect type classification criteria

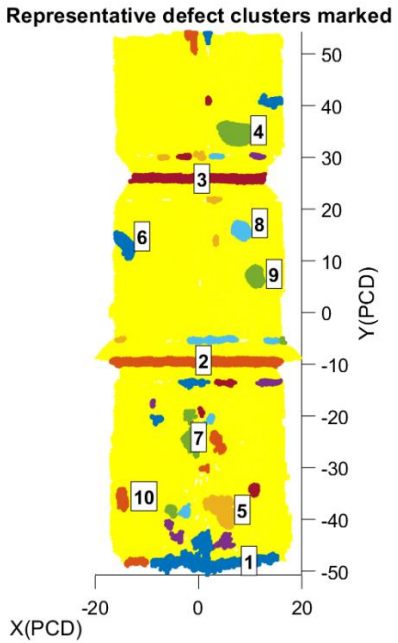
Results and discussion

Some of the identified defect clusters are marked and shown.

- Defect clusters are indexed, and their corresponding defect classification is shown in the table.
- Geometric analysis of the sample is also provided, with an error of less than 5%, confirming the accuracy of the system.



3D printed test specimen with defects highlighted in dotted circles and the specimen height(H) and width(W) are marked.

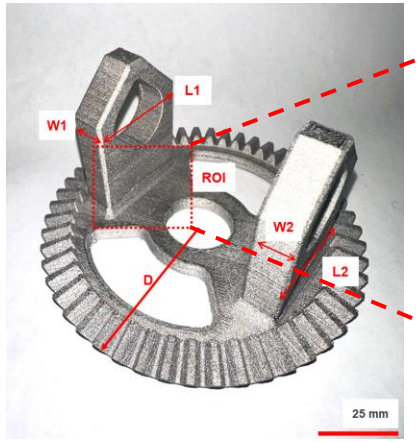


Defect Index	Defect Ratio	Centroid X	Centroid Y	Defect Type
1	0.64	3.9	-47.89	Elongated Bump
2	0.77	-0.13	-9.34	Scratch
3	0.81	-0.45	25.89	Scratch
4	0.92	6.83	34.46	Elongated Bump
5	0.81	4.31	-38.36	Rounded Bump
6	0.85	-14.38	13.13	Elongated Bump
7	0.69	-1.07	-24.2	Scratch
8	0.99	8.15	15.93	Rounded Bump
9	0.89	11.09	6.94	Bump
10	0.94	-14.86	-35.67	Elongated Bump

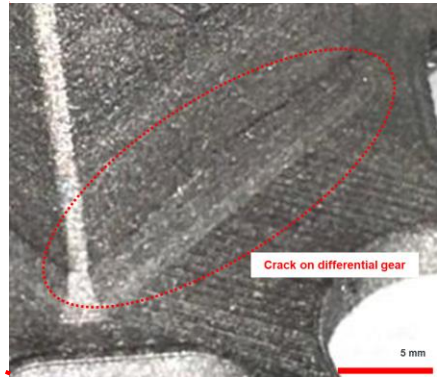
S.No	Section	Ground Truth(mm)	Measured Value(mm)	Error %
1	Max Height	102.57	105.2	2.56
2	Max Width	41.46	40.1	-3.28

Case Study

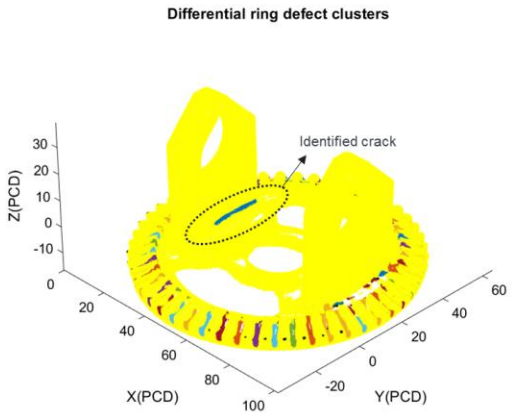
- The developed methods were applied to a real-world specimen, a ring gear from a differential assembly.
- The green part of the gear is printed using a metal FFF printer and sintered to obtain the final part.
- Geometric analysis error less than 5%.



Differential ring gear with dimensions and ROI marked



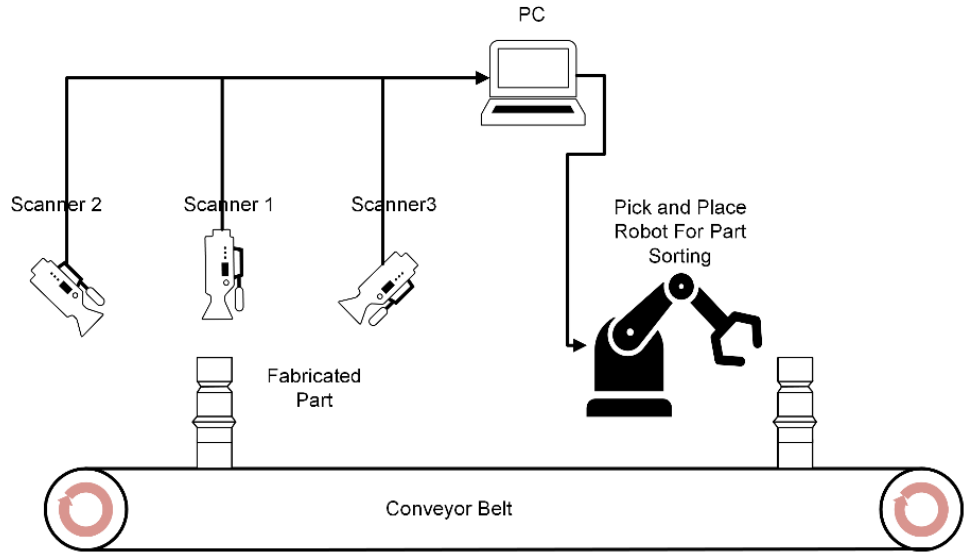
Magnified image of ROI



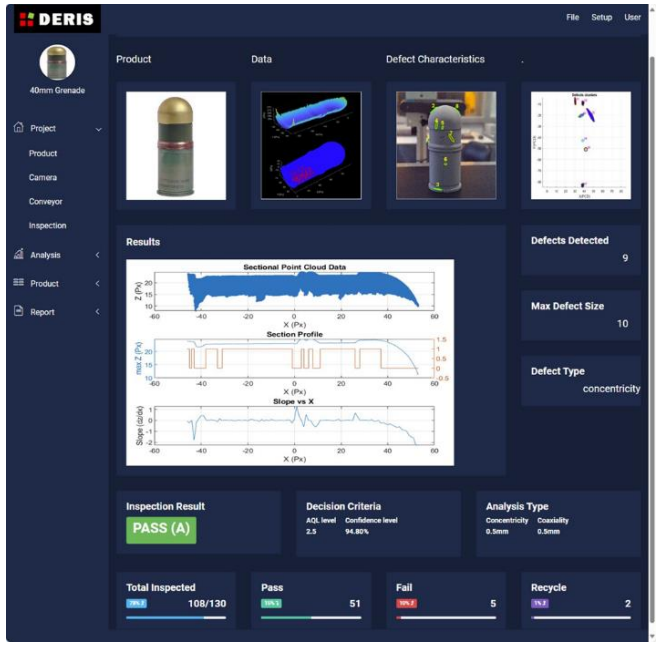
Defect Index	Defect Ratio	Centroid X	Centroid Y	Defect Type
1	0.14	24.73	20.58	Undefined

S.No	Section	Ground truth(mm)	Measured Value(mm)	Error %
1	W1	12.12	12.41	-2.39
2	L1	33.85	34.94	-3.22
3	W2	12.1	12.63	-4.38
4	L2	34.1	34.96	-2.52
5	D	100.95	102.03	-1.07

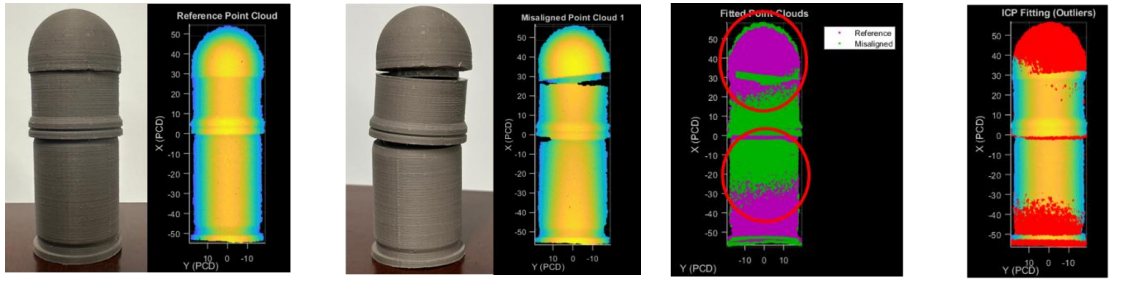
Future Work



Pick and place robot for part sorting



Interactive dashboard for process monitoring



Assembly misalignment detection

Percentage of outliers in the test point cloud: 53.11%