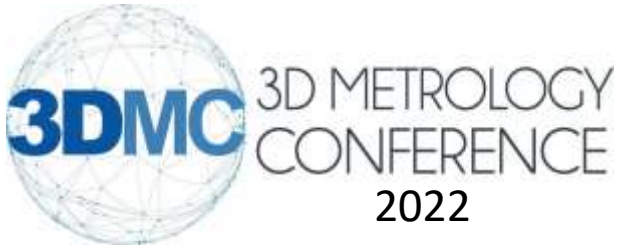

AUTOMOTIVE SURFACE INSPECTION VIA MACHINE LEARNING AND DEFLECTOMETRY

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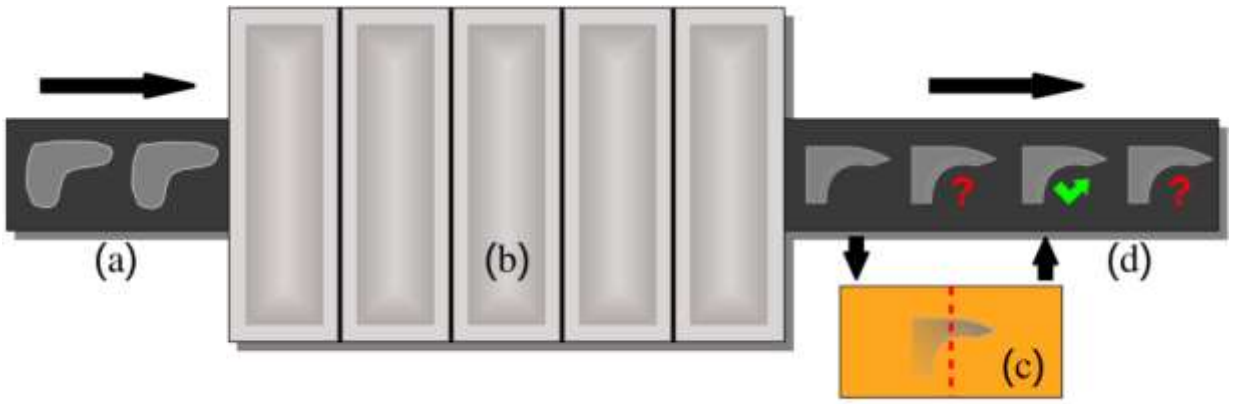
1) MOTIVATION

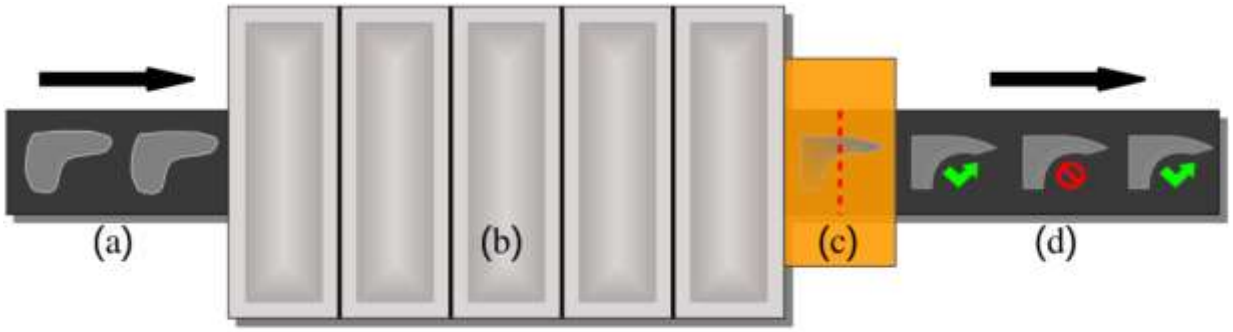
Why do we need photogrammetric surface quality control?

- Premium automobile manufacturers must ensure flawless vehicle exteriors
- Press shop production is subject to systematic and non-systematic errors
- Data-driven production demands comprehensive quality information
- Photogrammetry enables full-form contact-free inspection
- A transition to from at-line inspection to inline inspection is necessary



(a): metal blanks, (b): press line, (c): inspection system, (d): stamped components

[Hödel, 2019]



(a): metal blanks, (b): press line, (c): inspection system, (d): stamped components

[Hödel, 2019]

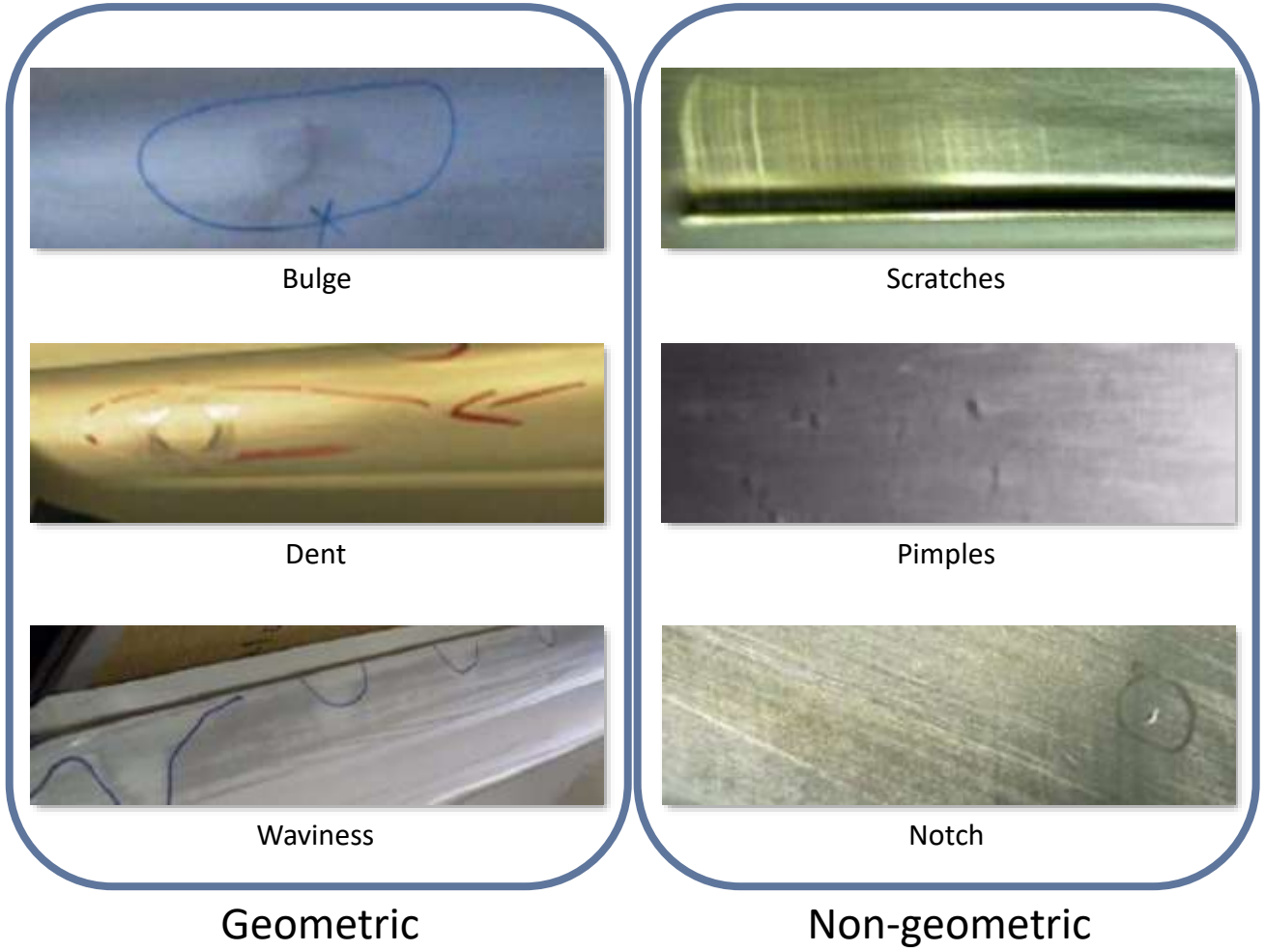
2) CHALLENGES FOR INSPECTION

- **Industrial challenges**
  - Vibrations
  - Lighting variations
  - Conveyor movement
- **Material challenges**
  - Degree of specularity
  - Oiling
  - Complex geometries
- **Data processing challenges**
  - Type of sensor
  - Time to measure
  - Finding ideal resolution

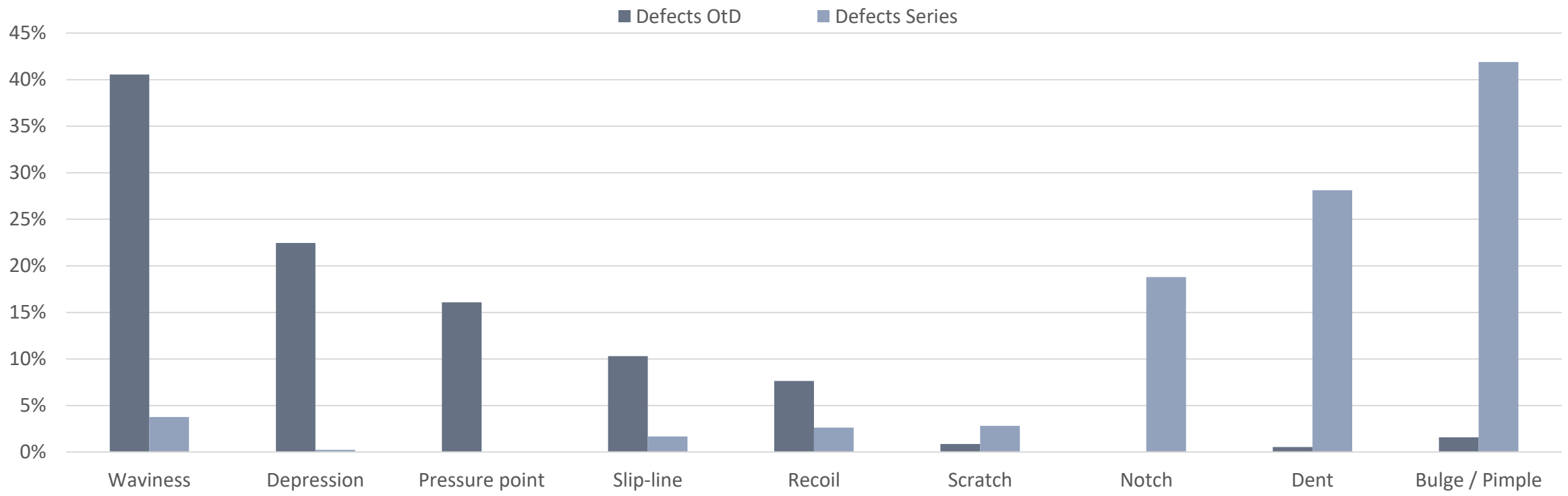
[Vogel, 2021]

3) SURFACE DEFECT SPECTRUM

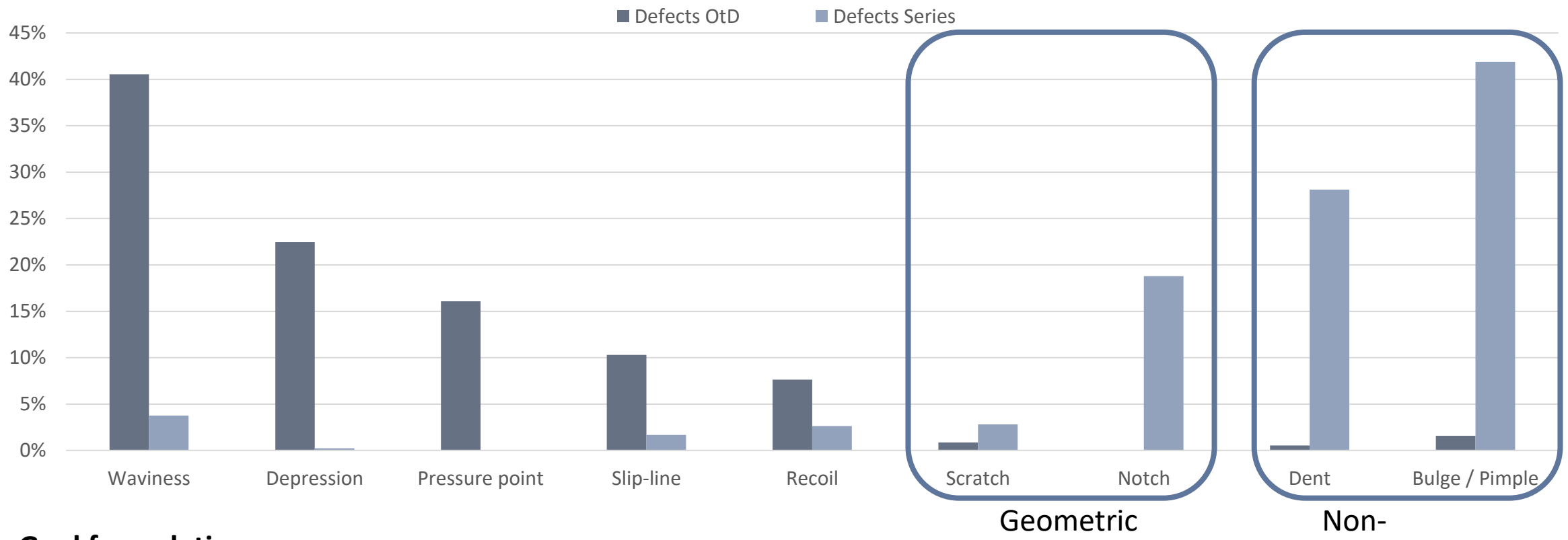
- **Surface defect landscape (press shop)**
  - Geometric defects
    - Bulges
    - Dents
    - Waviness
  - Non-geometric defects
    - Notches
    - Scratches
    - Pimples



3) SURFACE DEFECT SPECTRUM



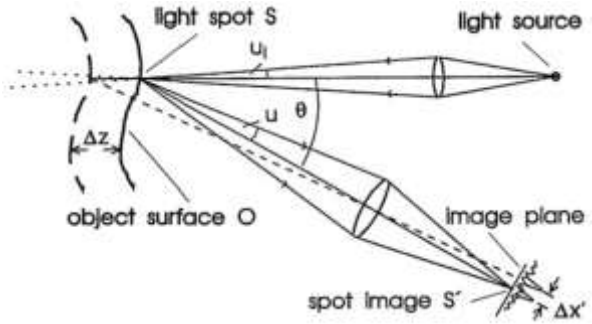
3) SURFACE DEFECT SPECTRUM



- **Goal formulation:**
  - "Research a photogrammetric surface inspection solution that is able to *detect*, *localize* and *classify* all customer-relevant surface defects, both geometric and non-geometric, on all stamped components."

4) TECHNOLOGIES

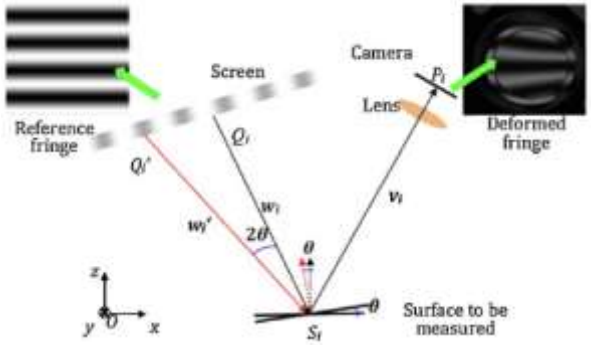
Laser Line Triangulation



[Dorsch et al., 1994]

- Defects: geometric
- Surface: diffuse
- Cycle time: mid to long

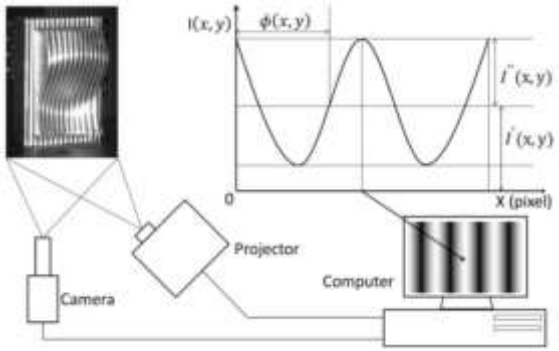
Deflectometry



[Zhang et al., 2017]

- Defects: geometric
- Surface: diffuse
- Cycle time: mid to long

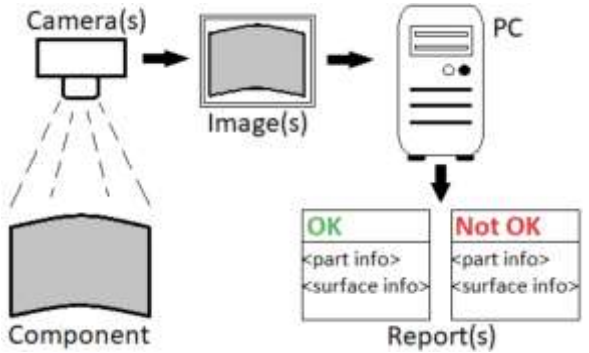
Fringe Projection



[Lin et al., 2016]

- Defects: geometric
- Surface: diffuse
- Cycle time: mid to long

Camera setups

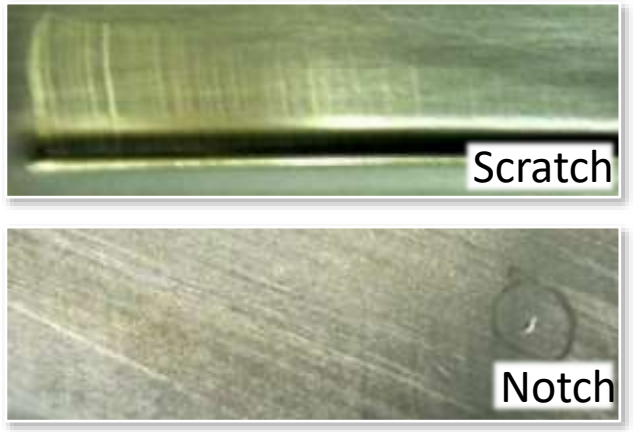


[Hödel et al., 2017]

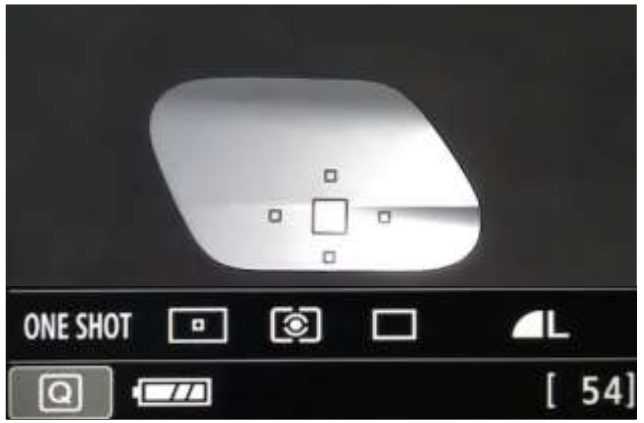
- Defects: non-geometric
- Surface: diffuse
- Cycle time: mid to long

5) EXPERIMENT OVERVIEW

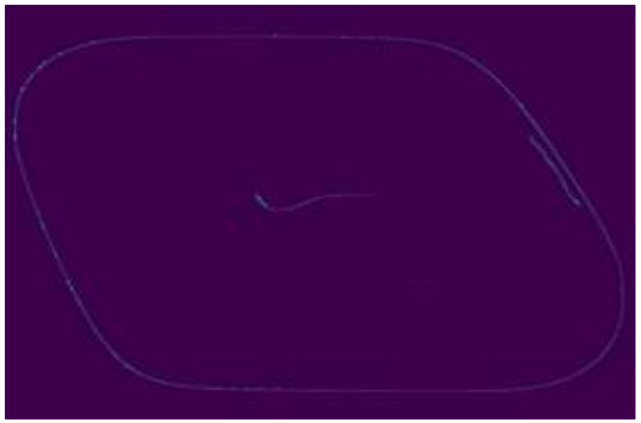
Non-geometric defects



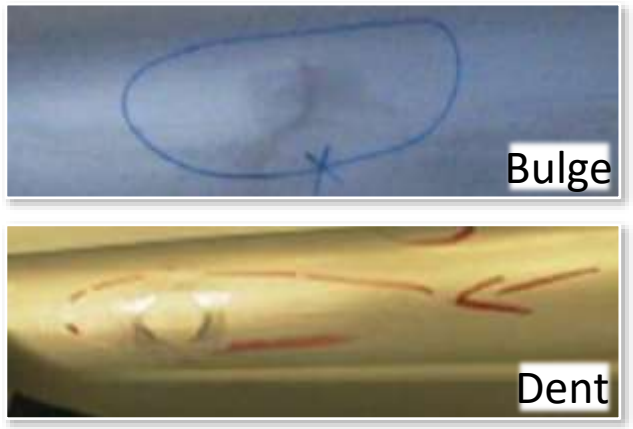
Camera setup



Detection

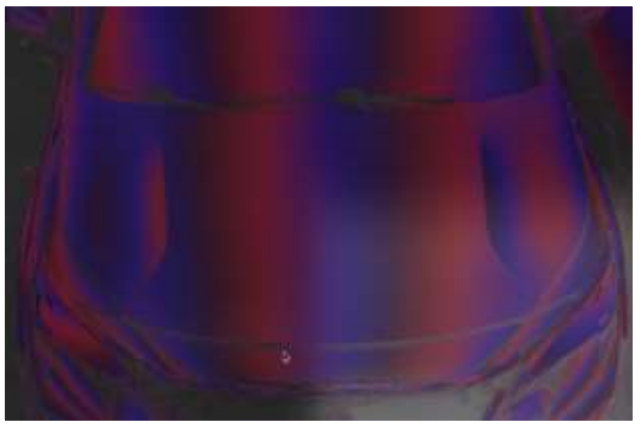


Geometric defets



LCS-Deflectometry

Detection



[du Preez, 2021]

6) RESEARCH QUESTIONS

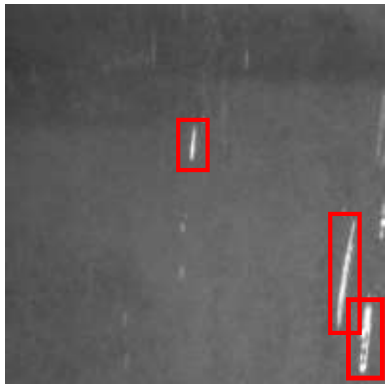
- How is the performance of non-geometric surface defect detection through image analysis in the vis. domain dependent upon factors such as: training data, resolution, oiling, lighting and vibrations.

- How is the performance of geometric surface defect detection through LCSD in the vis. domain dependent upon factors such as: training data, resolution, oiling, lighting and vibrations.

- How is the performance of geometric surface defect detection through LCSD in the infrared domain dependent upon factors such as: training data resolution, oiling, lighting and vibrations.

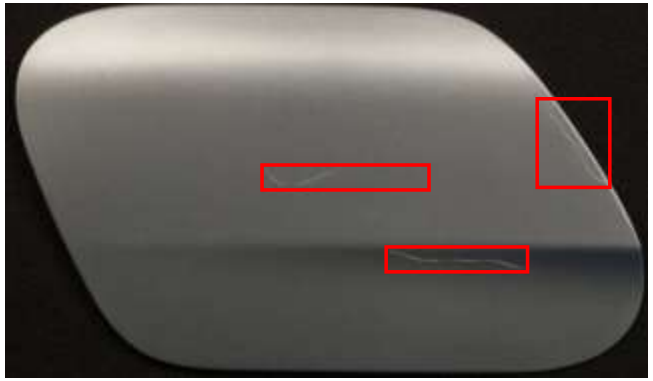
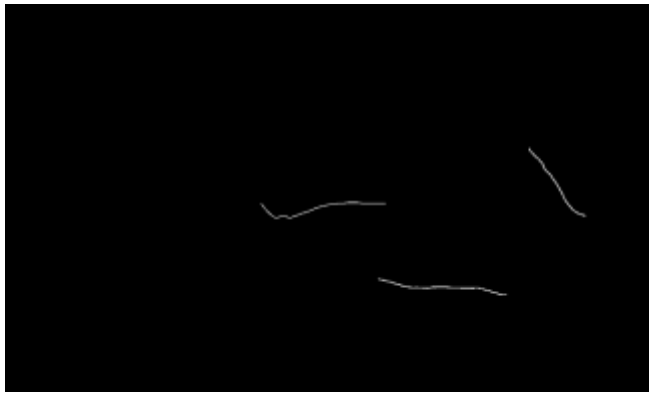
7) DATASETS

- **Open-source datasets**
  - NEU-900 / SD-saliency-900 [Song et al., 2020]


- 900 images:
  - 200x200
  - Grayscale
- Labels:
  - Bounding box
  - Pixel-wise

- **Own datasets**
  - “BMW-SDD-01”

- 3000 images:
  - 5000x4000 + 1/4 + 1/8 res.
  - Grayscale
- Labels:
  - Bounding box
  - Pixel-wise

8) APPROACH AND EXPERIMENTS

- Determine relative frequency and reworking costs associated with each defect type
- Install sensors in press line to determine vibrations
- Procure set of sample components with edge-case defects
- Determine aptitude of various technologies
- Create camera setup for deep learning detection (in-house)
- Order deflectometry prototype (cooperation with Axiscan S.A.S.)
- Benchmark camera detection with SOTA networks
- Receive and setup deflectometry prototype
- Transition deflectometry to infrared domain
- Hybridize camera detection with deflectometry detection

9) OUTLOOK / CONCLUSION

- Deliver proof of concept for in-line inspection system
  - Detection
  - Classification
  - Localization
- Expand upon the capabilities of deep learning for surface defect detection
  - Generative networks
  - Attention networks
  - Other architectures?
- Realize novel infrared latitude-encoded deflectometry system
  - Handle varying degrees of specularity
  - Reduction of complexity vs. traditional deflectometry
- Fill the press shop gap in comprehensive quality control
  - Contribution to Industry 4.0
  - Sustainable increase in quality

[Seth Tan, 2018]

THANK YOU FOR YOUR ATTENTION!

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