Towards enhancing Augmented Reality-guided Visual Inspection with Automated Deviation Analysis

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Motivation

- **Visual Quality Control**: Products in manufacturing processes must be checked for deviations from the CAD-model.
- Augmented Reality is used to assist this process. In real-time, the real object's pose is tracked[1] and the image is augmented with the CAD-model contours. Relevant sections are highlighted. The worker can label them "okay / not okay" (OK / NOK) directly in the app. **Automated highlighting of defects** could further enhance the effectiveness of the inspection.[2]
- In practice, fast setup times for new objects are often mandatory → System must work with new CAD-models without requiring data collected from the real object
- *CAD-based automated defect detection with a mobile camera* poses a problem without any existing datasets.

Research Question

How to define and create a dataset that enables the development of CAD-based automated defect detection with mobile cameras?

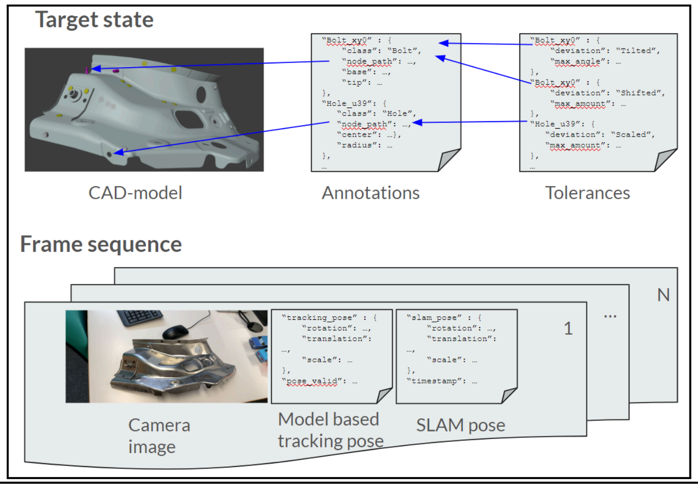
- System input / output; Performance metrics
- Additional data necessary for development
- What are cost-effective ways of creating such datasets?

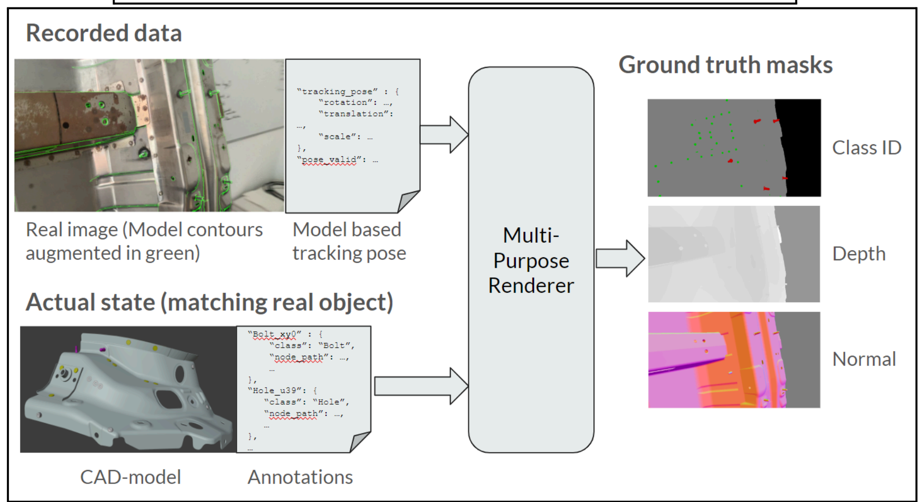
Defining a suitable dataset format *(First figure)*

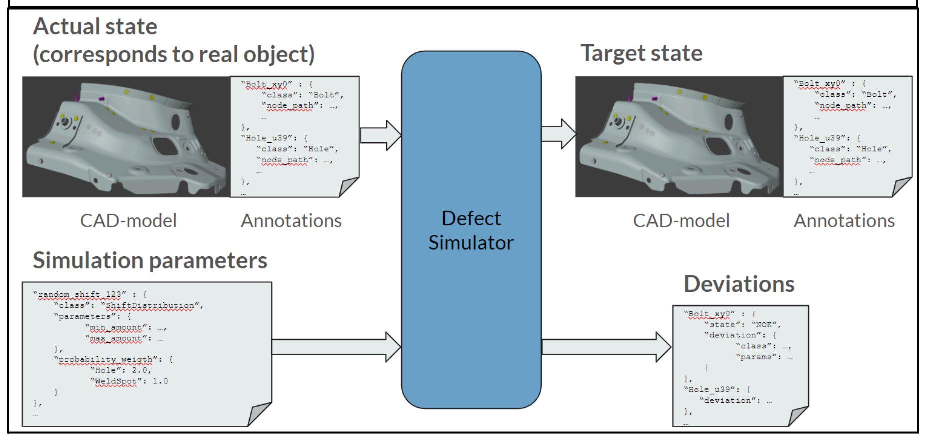
- Annotations: Class, Reference to node in the 3D model, Mathematical Parameters
- Tolerances: Per part for different defect types
- Frame sequence: Camera image, Tracking pose, SLAM pose
- Output: "OK / NOK / Unknown" label per part
  - NOK case: Defect type and parameters
- Performance metrics; Confusion matrix, Ratio of classified parts, Measurement error for defect parameters

Rendering training masks for subtasks *(Second figure)*

- Given CAD-model and annotations of the actual object's state → Rendering of ground truth masks for potential subtasks
  - Depth & Normal Estimation
  - Semantic segmentation







Simulation based dataset creation *(Third figure)*

- Often not possible to collect detailed data on the production line → Collect data from sample objects in the lab → Limited number of objects
- Real object and actual state (3D model + annotations) required.
- **Simulate defects by creating a target state with deviations** from the actual state. Modifies mesh and annotations. Record list of simulated deviations. **Combine with real images.**

- Supported defect types
  - Shifting, Tilting, Scaling
  - Removing / Adding parts
  - Deformation of parts (given the 3D model looks plausible)

Created dataset

- Remodeling and annotation of 8 different objects
  - Automobile use-case, steel and aluminum
  - Part classes: Stud, hole, weld spot, generic part
  - In total: 37 studs, 292 holes, 318 weld spots
- Modified existing AR application to record images and poses
  - SLAM pose from native SLAM support
  - Model tracking pose from VisionLib
  - 133 recorded sequences for a total of 146k frames
- Model tracking poses are mostly accurate (offset between augmented model and real object not visible). Inaccuracies occur mostly when the camera is moving → Good for testing (real conditions) but problematic for training (inaccurate masks)

Conclusion, Limitations, Future work

- Dataset format proposed that supports evaluating a solution and creation of 2D masks for various image processing subtasks.
- Simulation based dataset creation proposed.
  - Simulation provides target state and deviations. Lower effort compared to measuring real defects.
  - Real images → No domain gap
- Limitations
  - Not applicable for deformations like dents and surface defects like scratches
  - Physical object and corresponding model necessary
- Future work
  - Physically based rendering of simulated model
  - Implementation and evaluation of potential solutions
  - Extension of the dataset, supported part and defect types

References

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2. Seeliger, Arne, Long Cheng, and Torbjørn Netland. "Augmented reality for industrial quality inspection: An experiment assessing task performance and human factors." *Computers in Industry 151 (2023): 103985.*
3. Visometry GmbH. VisionLib documentation. https://docs.vis ionlib.com. [Accessed 12-04-2024]. 2024.