CTIMS: Automated Defect Detection Framework using Computed Tomography (CT)

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Introduction

Non-Destructive Testing (NDT) is one of the inspection techniques used in industrial tools inspection for quality and safety control. It is performed mainly using X-ray Computed Tomography (CT) to scan the internal structure of the tools and detect potential defects.

Nuclear power plants challenges

- Nuclear electricity, provide 15% of Electrical in Canada, is costly: high operational cost, long shutdowns duration
- Maintenance tool needs to be carefully inspected to ensure **high-safety** measure during maintenance operations
- maintenance-related outage costs **35$** per second **3M$** per outage
- All entered objects are manually checked and identified as complete

Literature Review

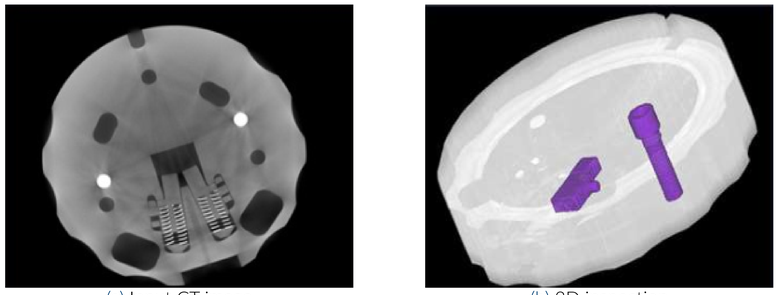
The existing CT-based defect inspection methods can be classified into two main categories:

- **image processing**: uses signal and image processing techniques to extract the defect's relevant features or pattern [1, 2].
- **Deep learning**: uses deep computer vision models trained on labeled datasets taking advantage of the rapid progress of this field [3] [4]

At the commercialization level, there exists some X-ray CT-based software for quality control in industrial applications using CT technology such as the Carl Zeiss AG [5], and VisiConsult X-ray Systems [6].

Research Contributions

- **Automate** the external/internal tool checking process (integrity check) using **AI** with X-ray Computed Tomography (CT) (resolution up to **nanometer-scale**)
- Improve the maintenance work by reducing the inspection time to **40 min per scan**.
- Integrate the **automation** process into the real-world scanner.
- Enable **incremental learning** to generalize the deep learning-based inspection for similar tools and defects without needing the reference scan



(a) Input CT image (b) 3D inspection

Figure 1. Example of the CT scan data and inspection

The CTIMS User Interface

The CTIMS system contains three main modules [7]:

- **Data management module**: prepare the scanner data in an SQL database,
- **Data preprocessing module**: Prep-process and prepare the input CT data (2D images /3D volume) using two main preprocessing functions: background subtraction and registration.
- **Defect inspection module**: perform an automated defect inspection based on different computer vision and deep learning-based inspection algorithms: defect classification, defect localization, and defect characterization.

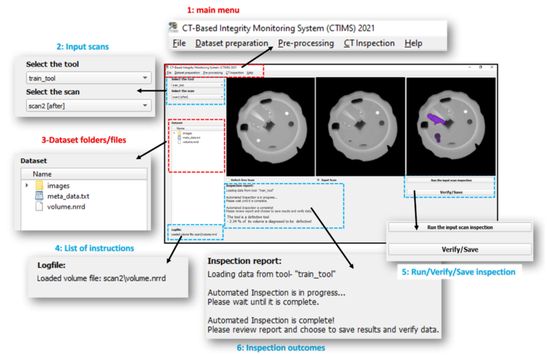
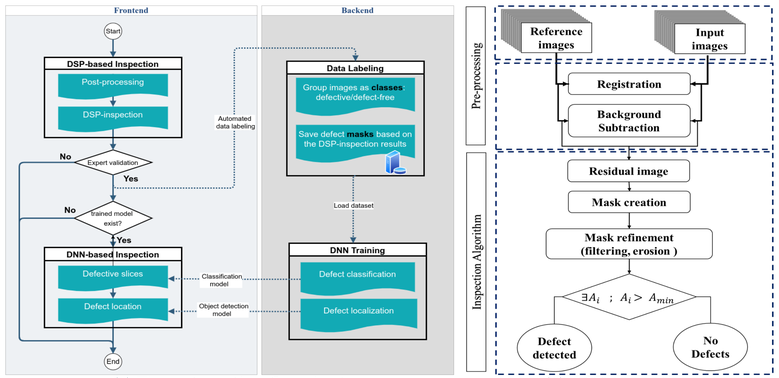


Figure 2. The CTIMS software for defect detection

The CTIMS Flowcharts

This CTIMS framework manages the data loading prep-processing and inspection based on an automated interaction with the user as follows:

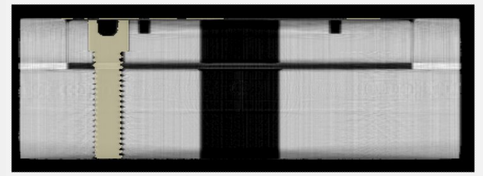


(a) The automation flowchart (b) DSP inspection

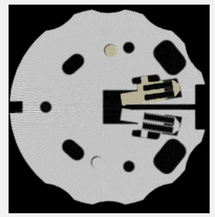
Figure 3. Illustration of the flowcharts of the different CTIMS modules

Example of Defect Inspection

- Inspection results showing the missing internal components:

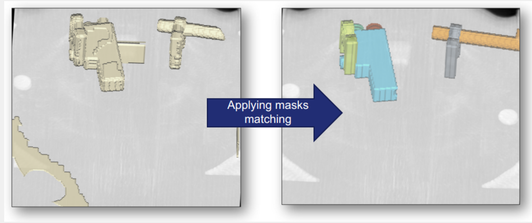


Side cross section



Top cross section

- Inspection refinement using annotation mask recognizing the damaged components:



Conclusions

- **Hybrid and automated inspection**: Combination of image processing and deep learning-based techniques in an automated framework
- **Three levels of inspection**: Defect detection, classification, characterization
- **Interactive and automated annotation**:
  - Create annotation/label based on the inspection results.
  - Semi-automated annotation using CAD files
  - Verify/adjust annotation using an interactive platform
- **Integrated incremental learning**: continually train the deep learning models as new scans are performed to ensure dynamic training and high-accuracy predictions.

References

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