MLOp Lifecycle Scheme for Vision-based Inspection Process in Manufacturing

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OpML ’19
Can you identify a defect?

- Vision-based Inspection: A process of visually checking products for compliance with specifications and requirements

![Defect Image]
ML in Manufacturing

- Attractive field for ML operation
  - Lots of data
    - Over 3,000 GB image data is captured from a single product part a day (Samsung).
  - Trivial and repeated tasks
    - Missing part inspection, dent inspection are trivial and error-prone tasks.
  - Boost productivity
ML in Manufacturing

- However, ML operation is difficult
  - Raw data
    - Data cleansing and labeling are required.
  - Lots of tasks in parallel
    - A single ML inference server cannot handle all requests.
  - Multiple stakeholders
    - Product inspector, product manager, operations manager, ML model developer, etc.
  - Need for re-training and/or transfer learning
    - Things change. Inspection policy and/or product may change.

*ML in manufacturing requires a different set of tools for different stakeholders*
Proposed Scheme

- **Key stakeholders in manufacturing**
  - **Product inspector**
    - Inspects products visually
    - Has a domain knowledge
  - **Model developer**
    - Designs and trains a deep neural network
    - An expert in machine learning
  - **Product manager**
    - Responsible for the overall product lifecycle
    - Monitors inspection model results
  - **Operations manager**
    - Responsible for the entire manufacturing operation
    - ML operation is adapted under supervision
Proposed Scheme

Key components for vision inspection systems
Image labeling support for different tasks
(classification, object detection, image segmentation)
Mostly used by product inspectors as many require domain knowledge
Intuitive user experience is very important
Design, train and test neural network with different sets of hyper-parameters

Labeled data from Data Labeler is imported directly
A centralized edge manager to store data, deploy and monitor ML models in production

- Storage manager: stores all labeled data
- Management service: deploys and monitors models running on inspection edges

Mostly used by product and operations managers

- Product manager: monitors defect ratio
- Operations manager: deploys (updated) model at right time
Inspection Edge

- Inspection edge runs an inference
  - Storage service: stores all image data locally
  - ML engine: loads and runs ML model on captured image data

- Models are deployed to inspection edges under the operations manager’s supervision
  - Model configuration, such as threshold, is configurable per edge
Evaluation

Implemented the proposed scheme

Data Labeler

Model Trainer

Edge Manager

Inspection Edge #1

Inspection Edge #2
Evaluation

- Applied to four production lines in two Samsung Electronics plants
- Defect detection accuracy improved by at least 32.8%
  (compared to the existing rule-based algorithms)

<table>
<thead>
<tr>
<th>Inspection area</th>
<th>Edges deployed</th>
<th>DNN model (Backbone)</th>
<th>DDA* improvement</th>
<th>Avg. inference time**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratch (smartphone)</td>
<td>88</td>
<td>Multi-class (ResNet50)</td>
<td>32.8%</td>
<td>760 ms</td>
</tr>
<tr>
<td>Dent (smartphone)</td>
<td>52</td>
<td>One-class (GAN)</td>
<td>40.0%</td>
<td>998 ms</td>
</tr>
<tr>
<td>Missing part (refrigerator)</td>
<td>9</td>
<td>Object detection (YOLO)</td>
<td>92.8%</td>
<td>1416 ms</td>
</tr>
<tr>
<td>Missing part (washing machine)</td>
<td>9</td>
<td>Object detection (YOLO)</td>
<td>85.6%</td>
<td>1632 ms</td>
</tr>
</tbody>
</table>

* Defect detection accuracy  ** 2.60GHz CPU with 8GB RAM

NORMAL  DEFECT

NORMAL  DEFECT
Case Study: Bolt Inspection

- Problem: Inspect refrigerator for missing bolt(s)
  - “Normal” if two bolts are in place
  - “Defect” otherwise
- Rule-based algorithms performed poorly
  - Altering position, brightness, shape, etc.
- Solution: Object detection model to identify two bolts

NORMAL
NORMAL
DEFECT
Case Study: Bolt Inspection

- Data Labeler
  - Annotated bolts from about 4,000 training images
- Model Trainer
  - Fine-tuned YOLOv2 (COCO dataset)
  - Augmented data during training
- Edge Manager
  - Deployed to 9 inspection edges
- Inspection edge
  - Inspects refrigerator for a defect
Case Study: Bolt Inspection

- Inspection model worked well, until
  - Camera orientation changed
  - New refrigerator products are added
  - False-positives

- So we re-trained and re-deployed the model
  - Annotated additional 1,000 training images
  - Fine-tuned from existing neural network
  - Re-deployed to inspection edges

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Conclusion

- Proposed ML operation lifecycle scheme for vision inspection systems in manufacturing
  - ML models are easily re-trained and re-deployed to production

- Identified five key components and four stakeholders
  - Data labeler for product inspector
  - Model trainer for model developer
  - Edge manager for product manager and operations manager
  - Inspection edge for operations manager

Future work
- Apply the scheme on other production lines
- Automate re-train, re-deploy operations
Thank you