SAMSUNG Research

MLOp Lifecycle Scheme for Vision-based Inspection Process in Manufacturing

May 20, 2019

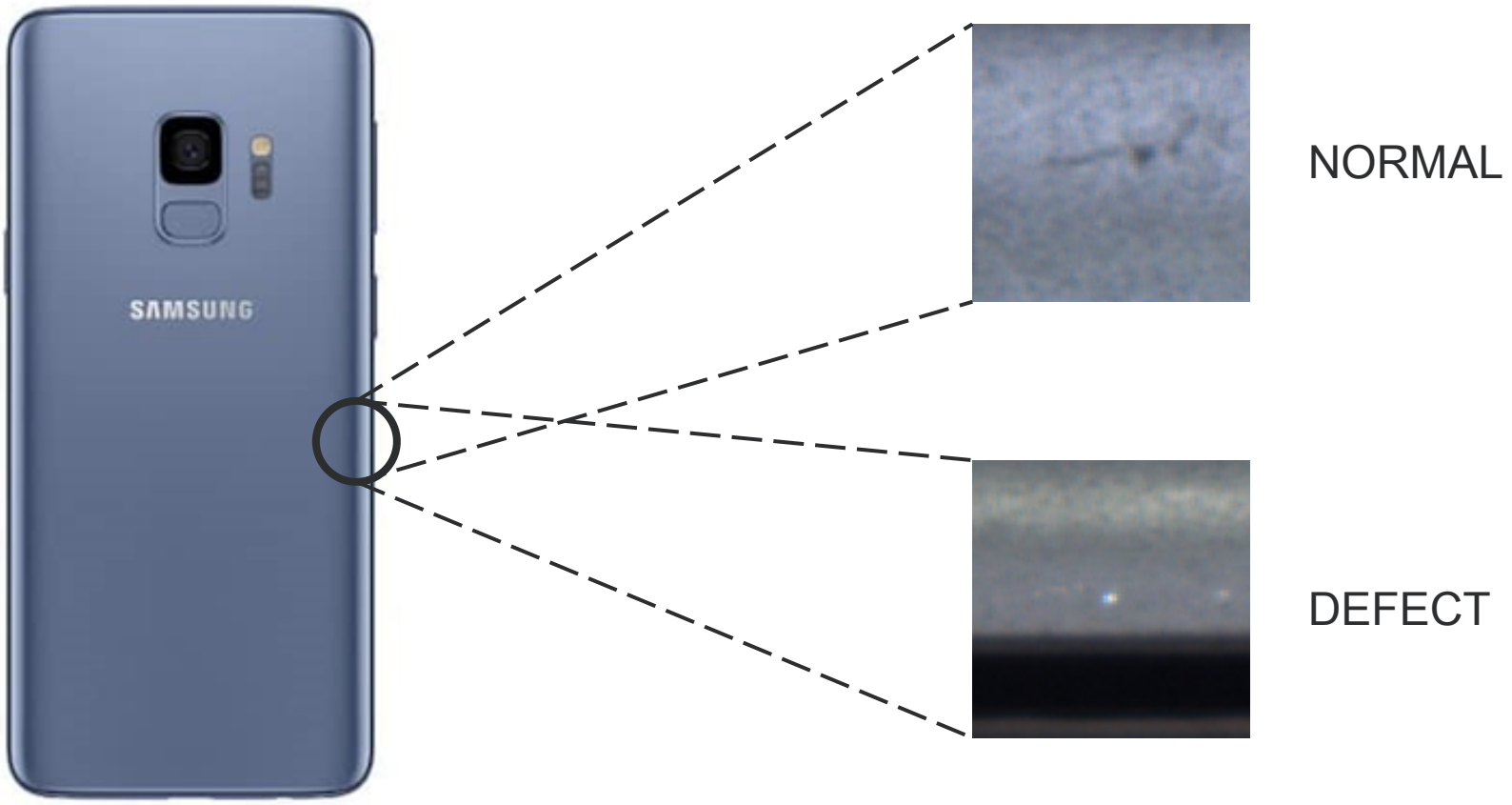
Junsung Lim, Hoejoo Lee, Youngmin Won, Hunje Yeon



OpML '19

Can you identify a defect?

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



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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



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ML in Manufacturing

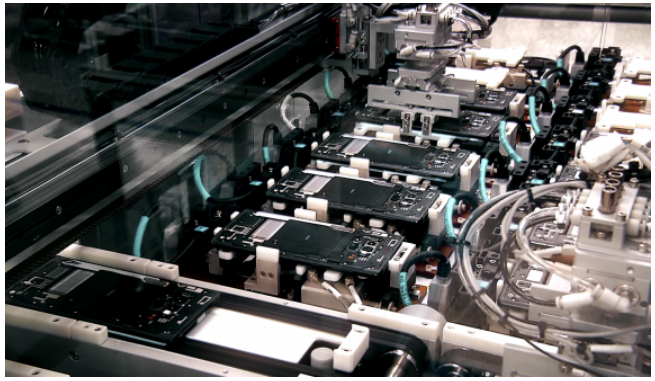
- However, ML operation is difficult
  - Raw data

    Data cleansing and labeling are required.
  - Lots of tasks in parallel

    A single ML inference server can not 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

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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



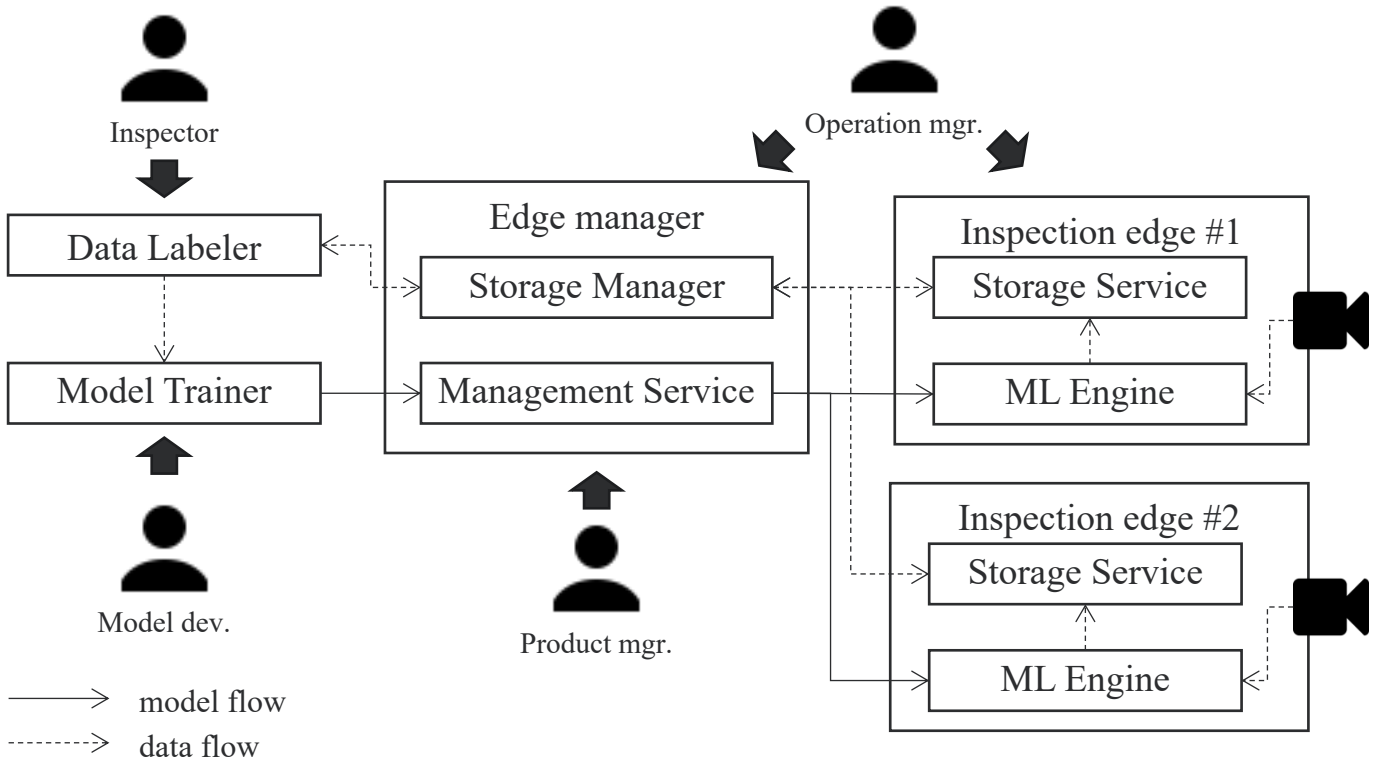
Operations manager

- Responsible for the entire manufacturing operation
- ML operation is adapted under supervision

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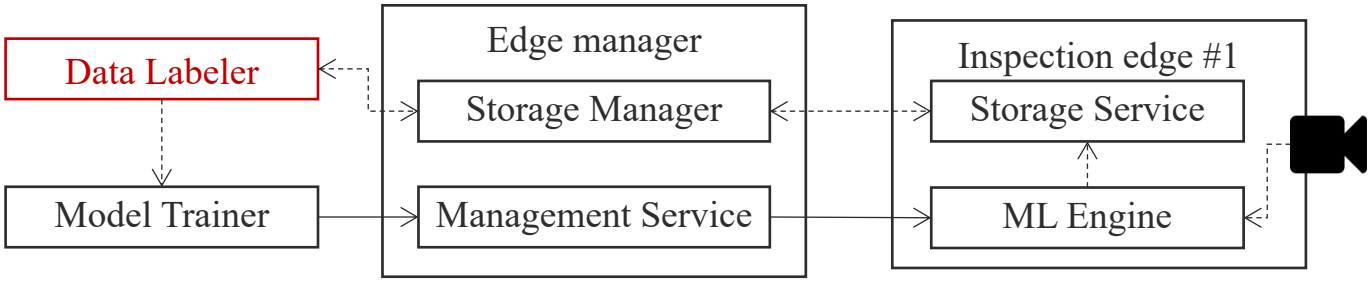
Proposed Scheme

- Key components for vision inspection systems



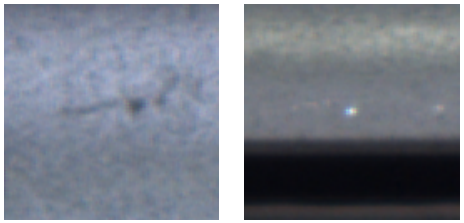
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Data Labeler for Inspectors



- Image labeling support for different tasks

  (classification, object detection, image segmentation)
- Mostly used by product inspectors as many require domain knowledge

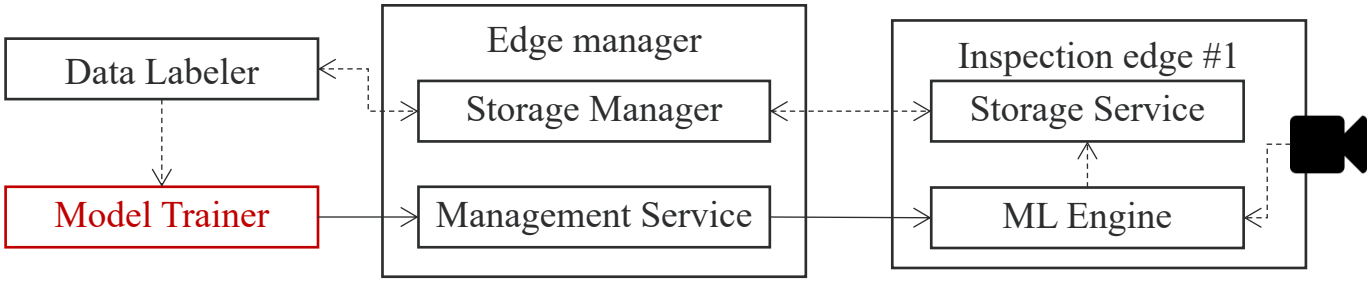


NORMAL DEFECT

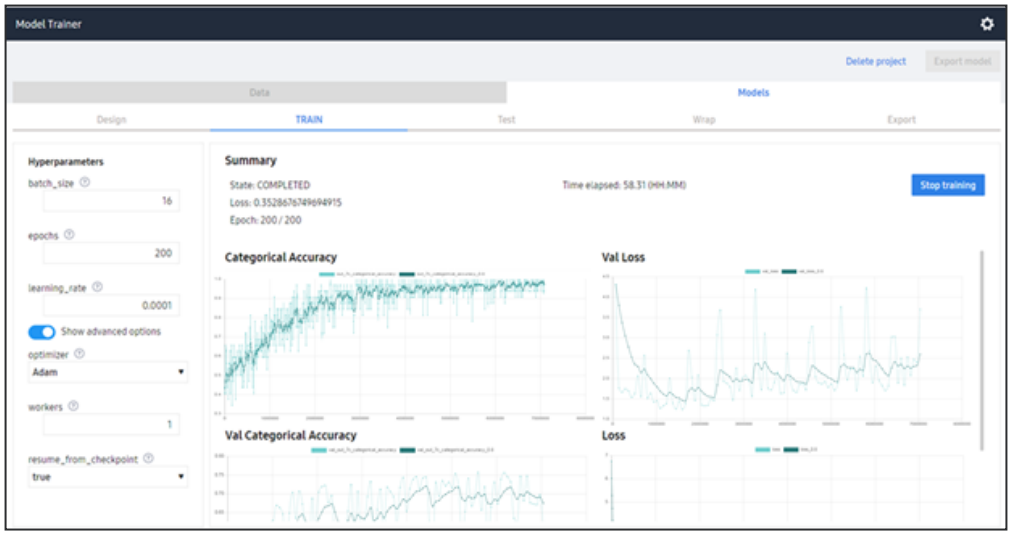
- Intuitive user experience is very important

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Model Trainer for Model Developers

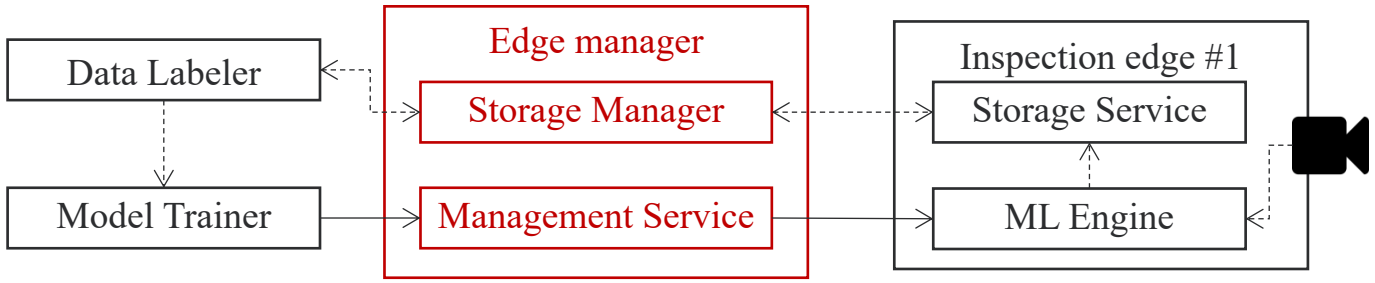


- Design, train and test neural network with different sets of hyper-parameters
- Labeled data from Data Labeler is imported directly



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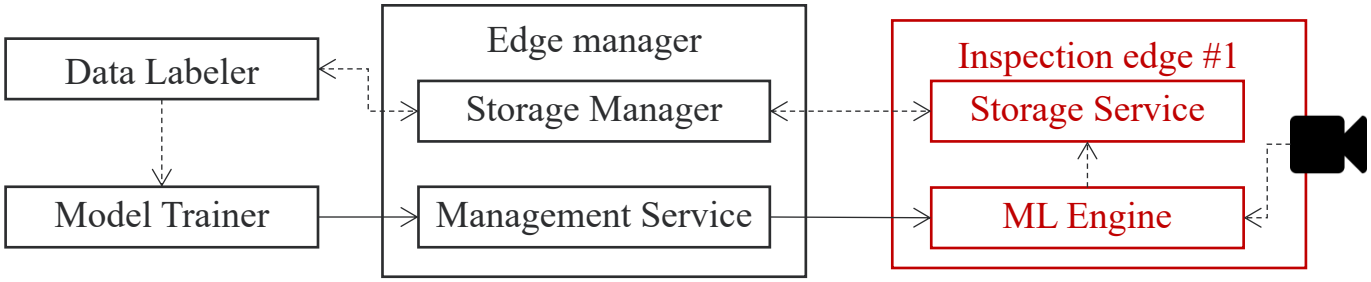
Edge Manager for Managers



- 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

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Inspection Edge



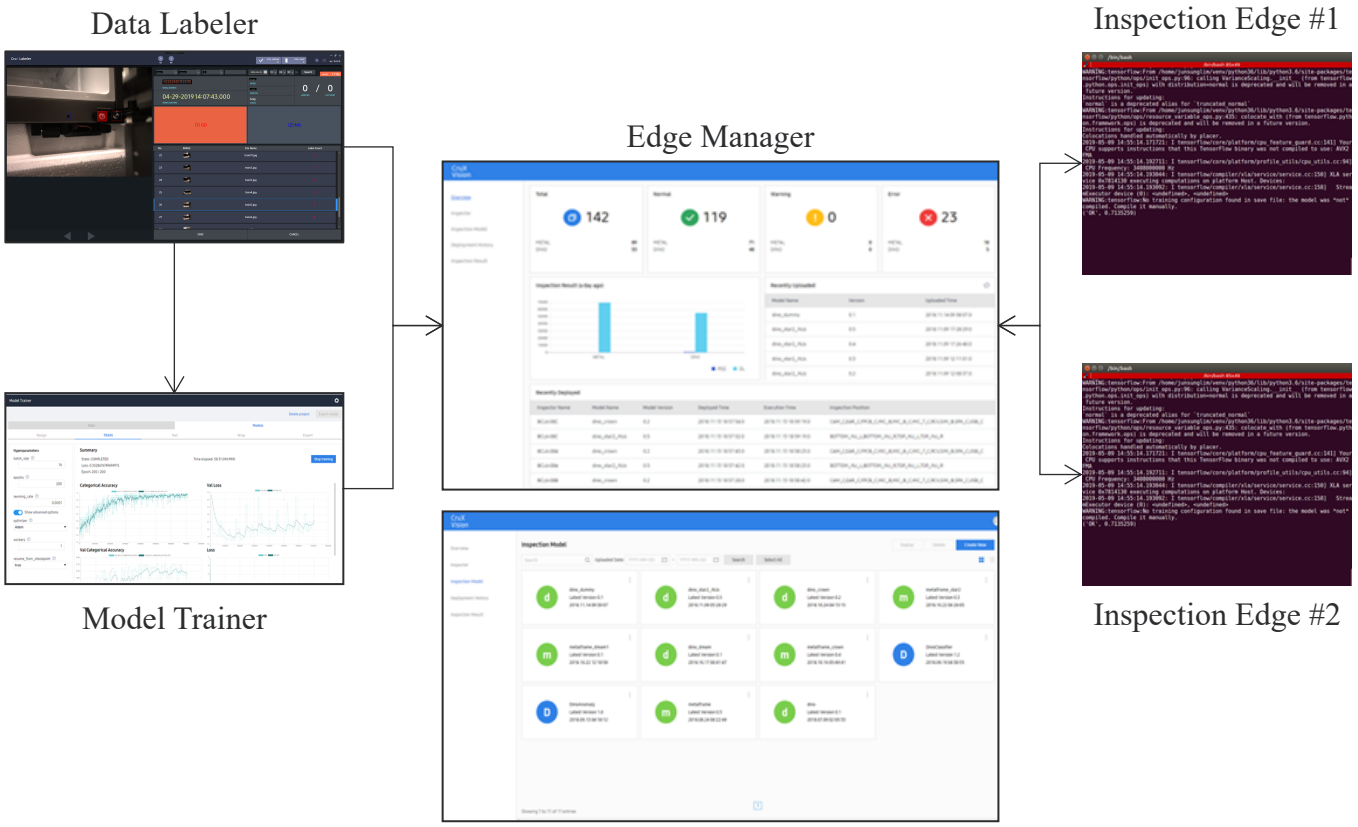
- Inspection edge runs an inference
  - Storage service: stores all image data locally
  - ML engine: loads and runs ML model on captured image data

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

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Evaluation

- Implemented the proposed scheme



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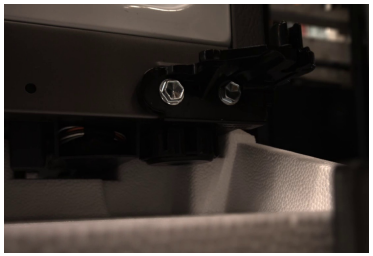
Evaluation

- Applied to four production lines in two Samsung Electronics plants
- Defect detection accuracy improved by at least 32.8%

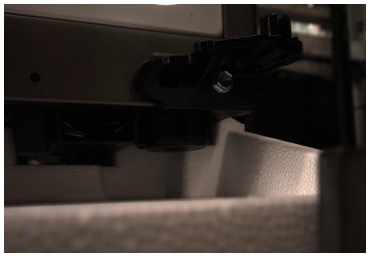
  (compared to the existing rule-based algorithms)

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

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



NORMAL



DEFECT



NORMAL



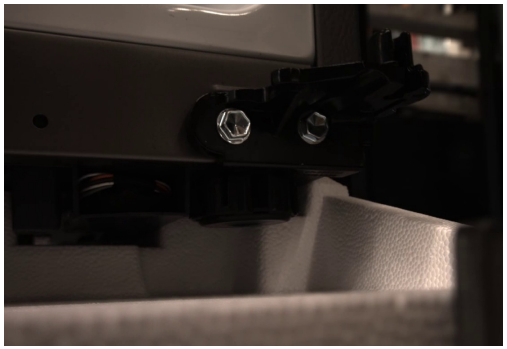
DEFECT

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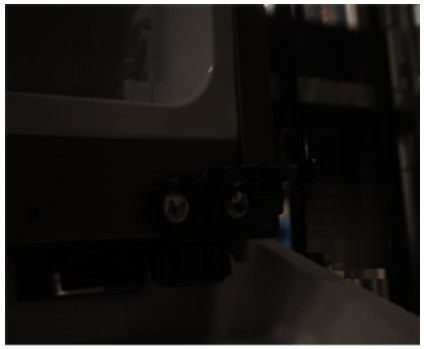
Case Study: Bolt Inspection

- 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

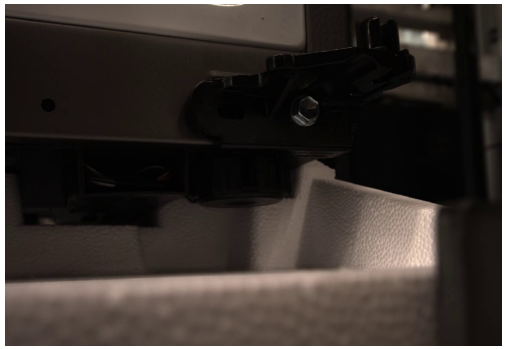




NORMAL



NORMAL



DEFECT

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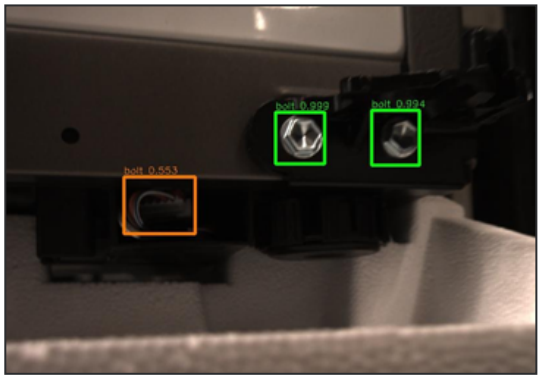
Case Study: Bolt Inspection

- 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

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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

Inspection area	Edges deployed	DNN model (Backbone)	DDA improvement	Avg. inference time
Missing part (refrigerator)	9	Object detection (YOLO)	92.8%	1416 ms

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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

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Thank you