Integration and Comparison of Vision Models for Smart Inspection Cell

Case Study

Intelligent Systems in Production

Technische Hochschule Deggendorf

Campus Cham

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Contents

Overview

- **Industrial Problem:-** The detection of surface defects remains challenging due to the limitations of manual and rule-based inspection methods. Subtle defects such as cracks and pitting are often missed, leading to reduced reliability and increased downstream failures.

- Deep learning models detects surface defects in metal surface but real time integration is underexplored.

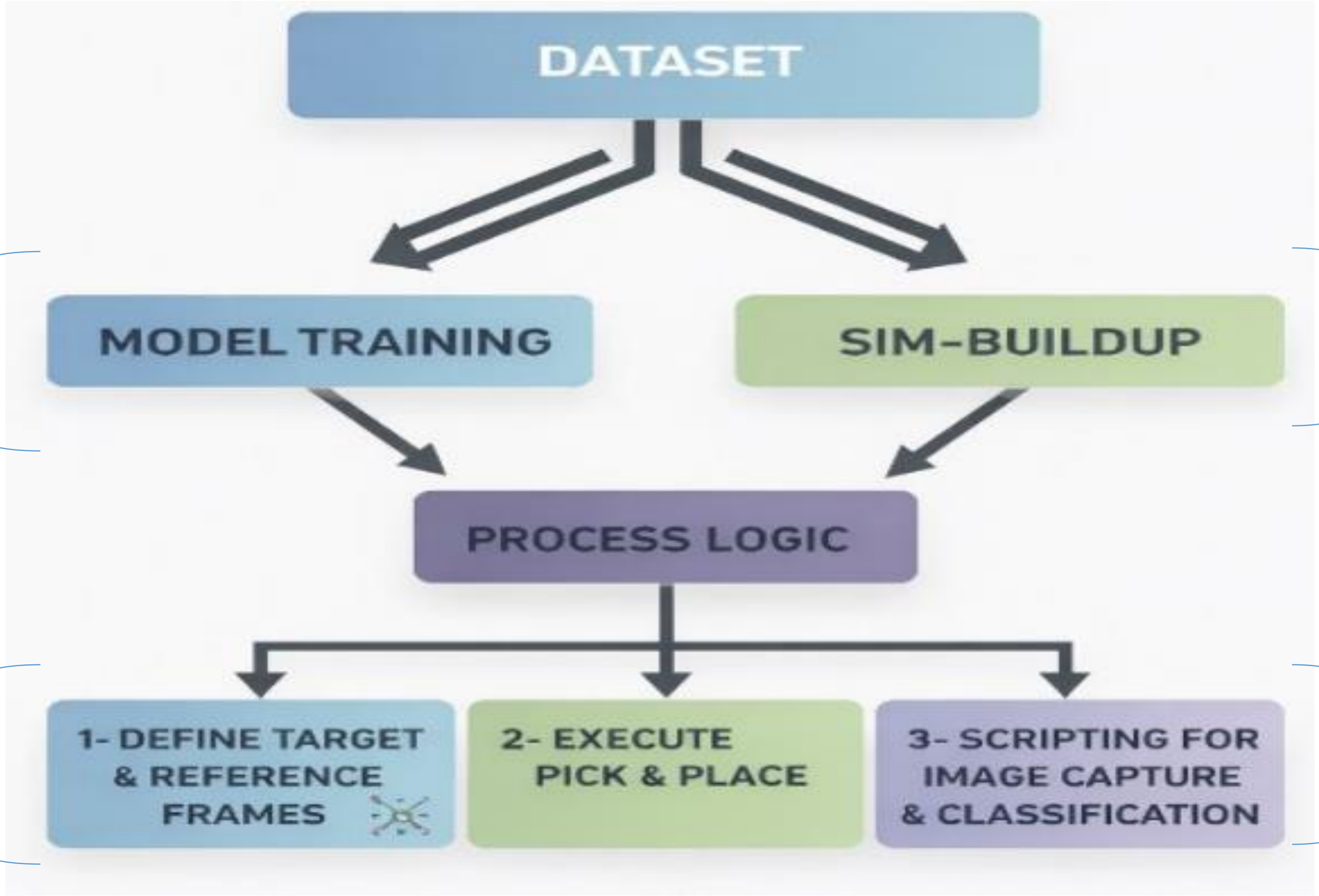
- **Objectives:-** This work investigates a data-driven vision-based inspection framework integrated with robotic handling to address these challenges.

- Comparision of YOLOv8 and MobilenetV2 models for best fit based on production critical metrics.

Dataset Generation

- **Dataset contents:-** Synthetically generated spur gear with void, scratch defects
- **Spur gear Prototype:-** Catia generated -> 3D .step files
- **Input format for Training:-** .png images, .txt annotation boxes
- **Assumptions:-** Gear tooth pitch, profile is considered irrelevant, defect types replicates real life defects
- **Units:-** All measurements in millimetres, down-scaled to **0.2x** in Simulation
- **Dataset Generation Process:-**

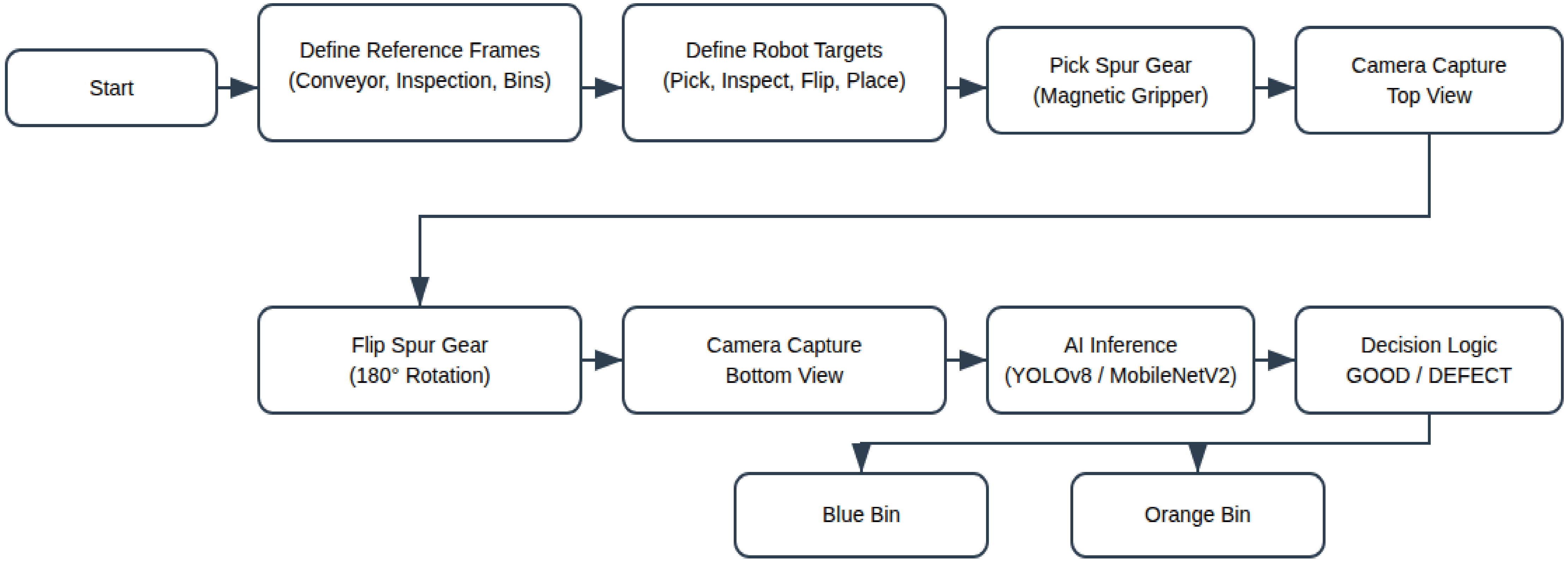
End-to-End Algorithm + Simulation Pipeline



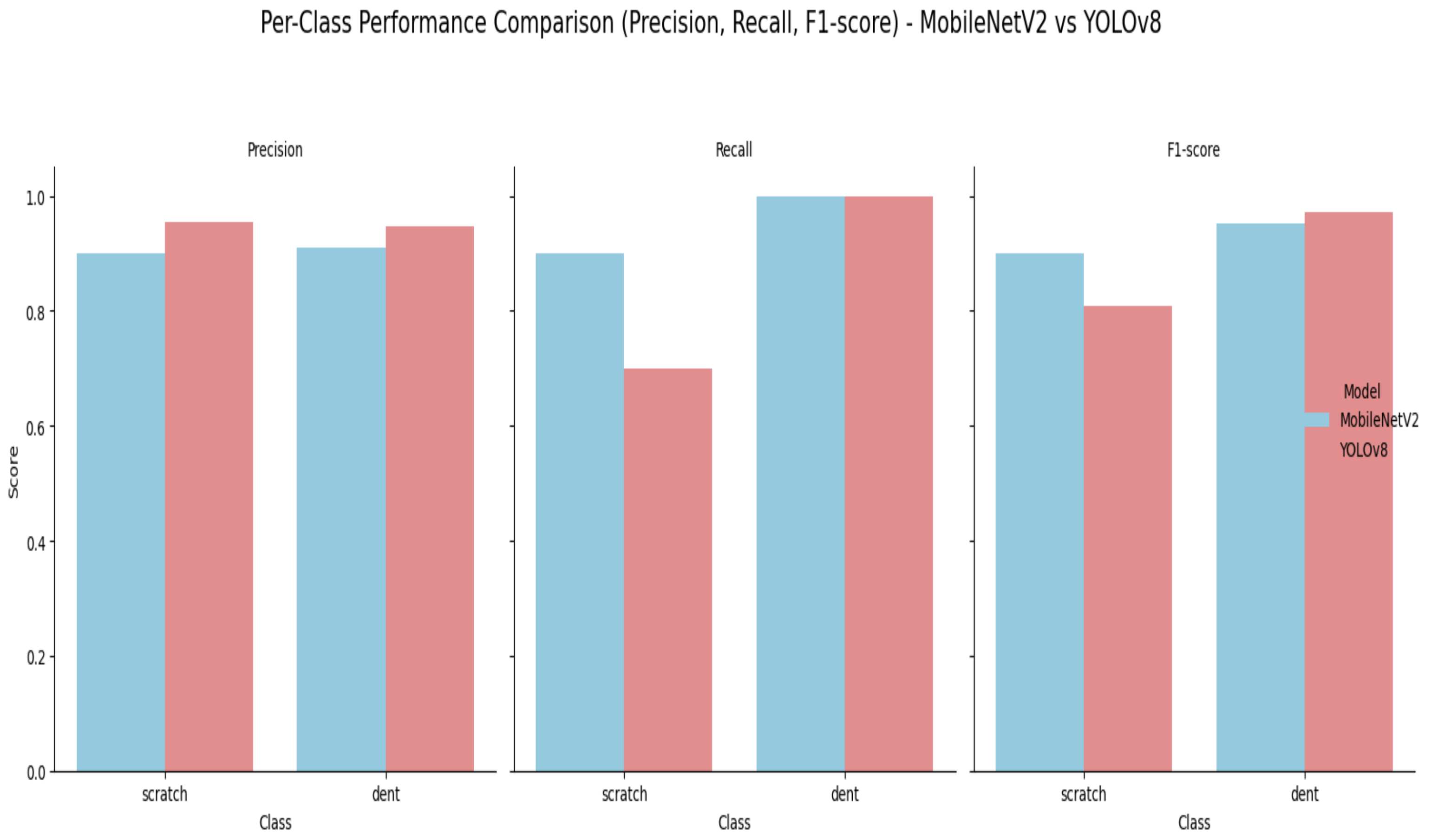
Phase 1

Phase 2

Simulation Pipeline



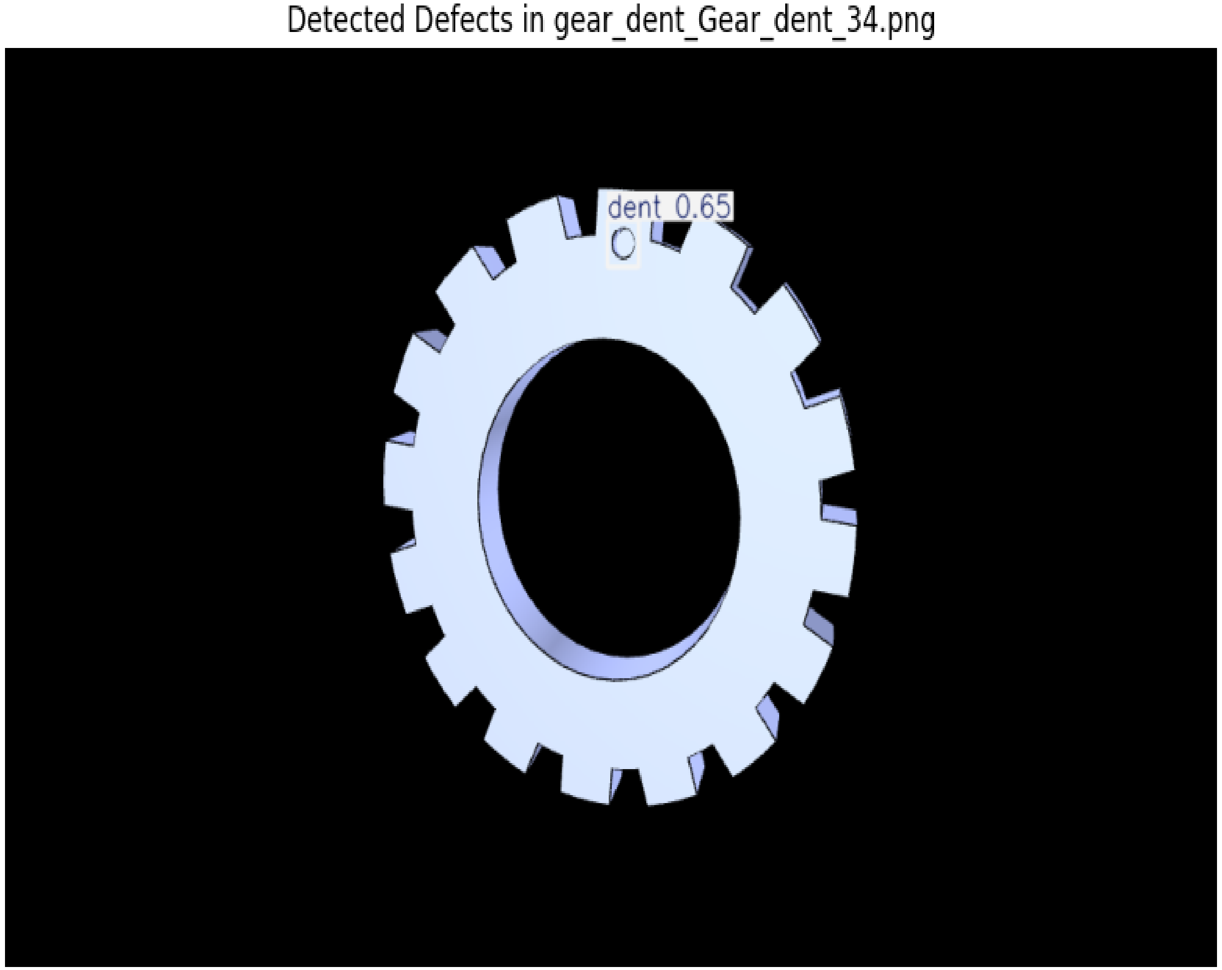
Training Results



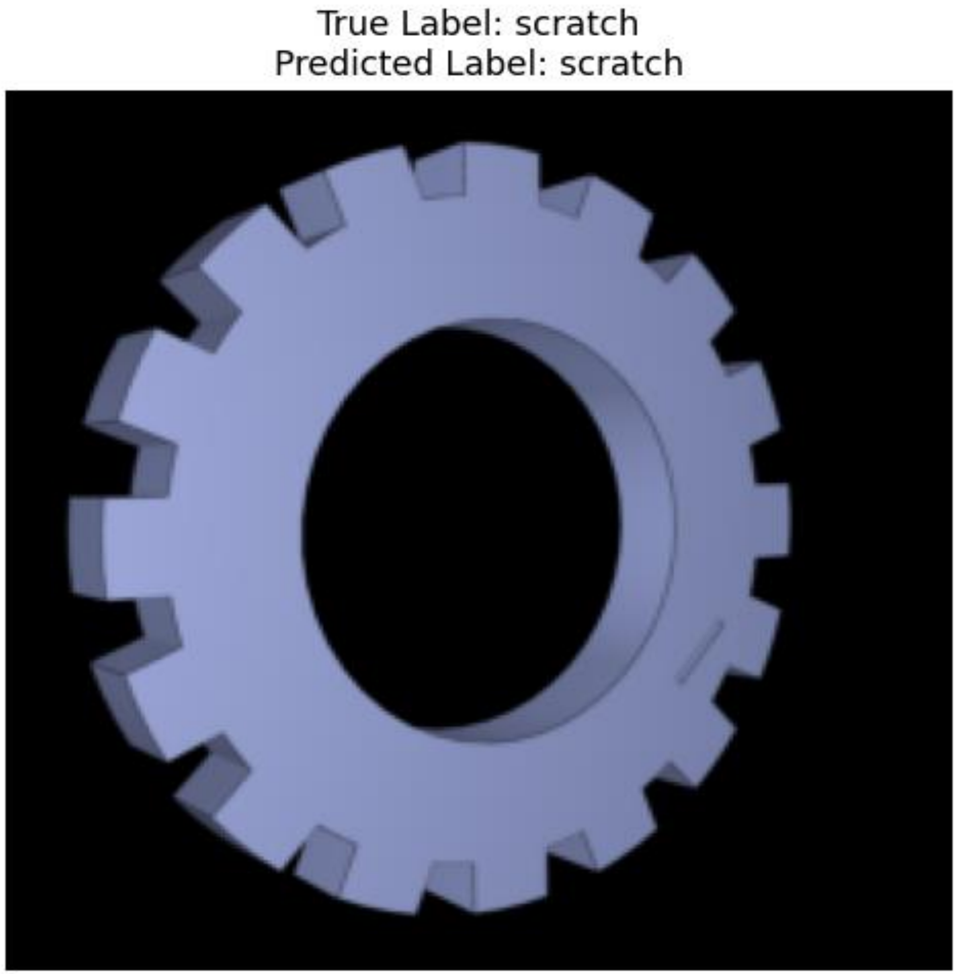

```
--- Per-Class Performance Comparison ---
         Model    Class  Precision  Recall  F1-score
0  MobileNetV2  scratch   0.900000     0.9  0.900000
1  MobileNetV2     dent   0.909091     1.0  0.952381
2       YOLOv8  scratch   0.954000     0.7  0.807497
3       YOLOv8     dent   0.946000     1.0  0.972251


--- Overall Performance Comparison ---
               MobileNetV2  YOLOv8
Metric
Test Accuracy     0.933333     NaN
mAP50                  NaN   0.964
mAP50-95               NaN   0.505
```

Defect Classification Results

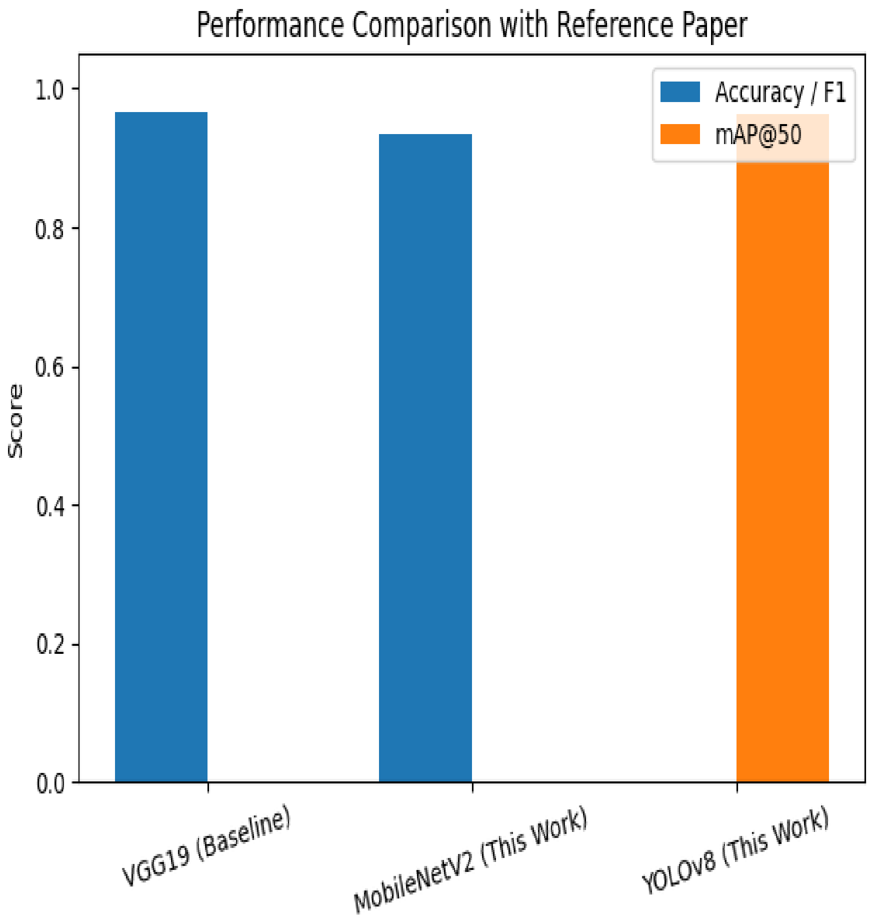


Classified from trained Yolov8



Classified from trained MobileNetV2

Benchmark Comparison



Model	Task Type	Precision	Recall	F1 / Accuracy	mAP@50	Localization
VGG19 (Wan et al., 2021)	Classification	0.9675	0.9676	0.9674	—	❌
MobileNetV2 (This Work)	Classification	~0.90–0.91	~0.90–1.00	0.9333	—	❌
YOLOv8 (This Work)	Detection	0.94–0.95	0.70–1.00	—	0.964	✅

Comparison with Reference Paper (Baseline VGG19)

Validation/Proof

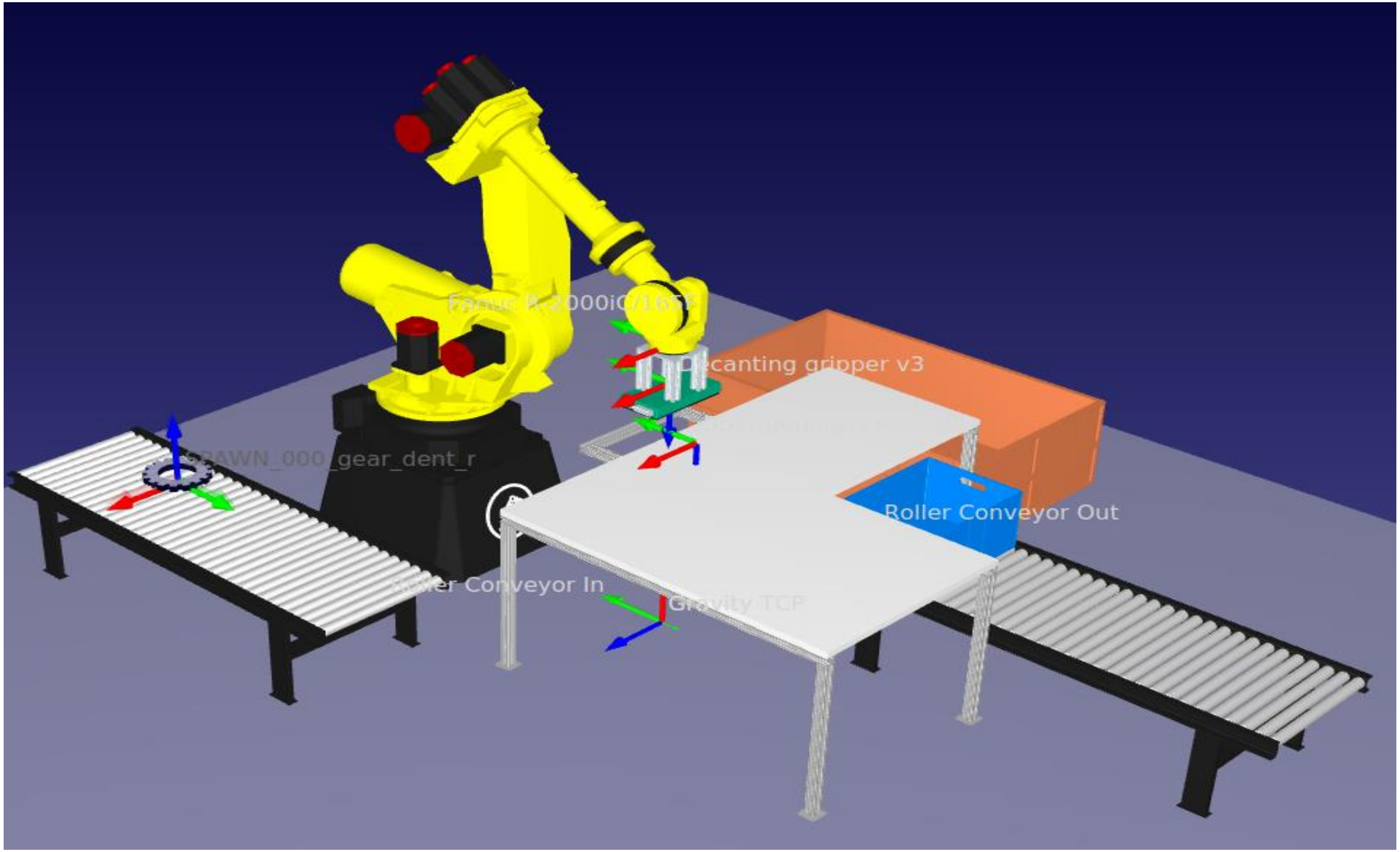
Validation Methodology:

- Model performance was validated on a **held-out test dataset** independent of the training and validation splits, ensuring unbiased evaluation.
- For object detection, **YOLOv8** was assessed using standard detection metrics, achieving an **mAP@50 of 0.964** and **mAP@50–95 of 0.505**, with per-class precision values exceeding **0.94** for prominent defect categories (e.g., scratch and dent).
- For classification, **MobileNetV2** achieved a **test accuracy of 93.33%**, with corresponding F1-scores consistently above **0.90**, indicating stable class-wise discrimination.

Reliability and Statistical Confidence:

- cross-validation through **two complementary model architectures** (detection and classification) provides independent confirmation of defect recognition capability, strengthening the reliability of the results.

Simulation Setup in RoboDK



Discussion, Tangible Outcomes & Gaps

Tangible Outputs

- Synthetic spur gear defect dataset with YOLO annotations
- Trained YOLOv8 and MobileNetV2 models with evaluation metrics
- RoboDK-based smart inspection cell simulation with sorting logic

Gaps & Next Steps

- Vision–robot inference integration not yet automated
- Python script for image capture and model inference pending
- Future work: close vision–robot loop and validate on real images

"The core inspection pipeline is established, with integration-focused tasks remaining"

Key References

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- H. Nguyen, “Mobilenetv2 + enhanced feature pyramid for fast object detection,” Journal of Theoretical and Applied Information Technology, vol. 98, no. 21, pp. 3341–3352, 2020

- M. Sandler, A. Howard, M. Zhu, A. Zhmoginov, and L.-C. Chen, “Mobilenetv2: Inverted residuals and linear bottlenecks,” in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2018, pp. 4510–4520

Thank You

https://github.com/Pallelayaswitha1/Integration-and-Comparison-of-vision-models-for-smart-inspection-cell/tree/main