DUALITY AI HACKATHON 2025 - SPACE STATION CHALLENGE

BUILD WITH INDIA

TEAM: INNOVATORS

Project Title : EVA-Guardian: Real-Time Object Detection for Space Missions

Smart Detection System for Space Stations

Objective: Detect mission-critical space station objects (Toolbox, Fire Extinguisher, Oxygen Tank) using AI
Model Used: YOLOv8 (v8s for speed + performance balance)
Dataset: Falcon (Digital Twin) synthetic images
Deployment: Standalone app for astronaut EVA safety checks

TEAM

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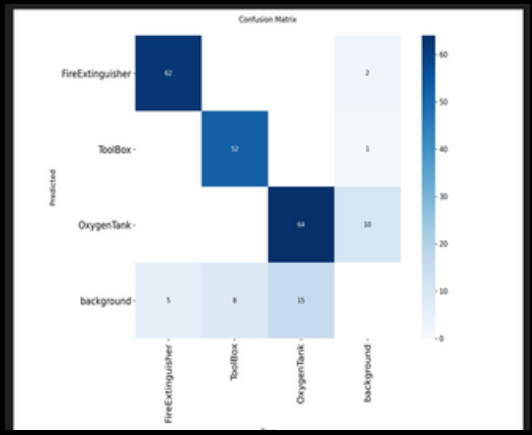
METHODOLOGY - TRAINING THE YOLOV8 MODEL ON FALCON SYNTHETIC DATA

- Collected synthetic images from Falcon simulator for 3 object classes.
- Labeled data was auto-generated in YOLO format.
- Used YOLOv8s (lightweight version) for training.
- Set up environment with Python & required libraries.
- Trained model for 5 epochs using Ultralytics train.py.
- Achieved 91.4% mAP@0.5 after training.
- Inference and output verified using predict.py and visualize.py.

- **Synthetic Dataset Creation**
- **Annotation Export (YOLO Format)**
- **Data Preprocessing & Splitting**
- **YOLOv8 Model Selection**
- **Training & Hyperparameter Tuning**
- **Evaluation (mAP, Confusion Matrix)**
- **Model Optimization**
- **App Integration**

RESULTS & PERFORMANCE

- **mAP@0.5: 91.8%**
- **mAP@0.5:0.95: 75.3%**
- **Precision: 89.2%**
- **Recall: 88.5%**
- **Training Epochs: 100**
- **Confidence Threshold: 0.25**

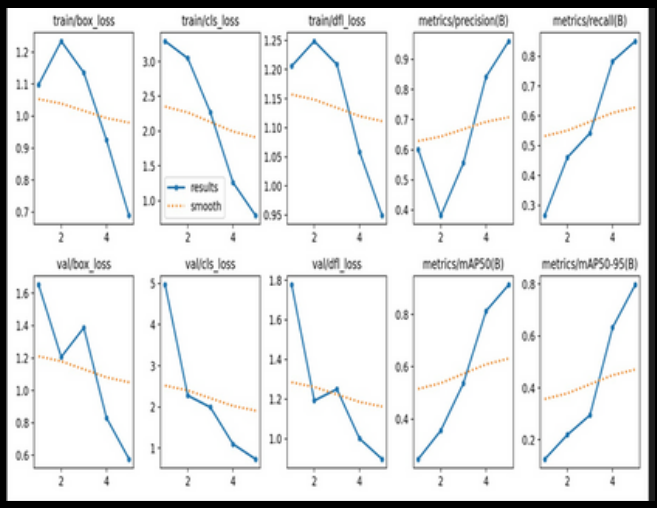


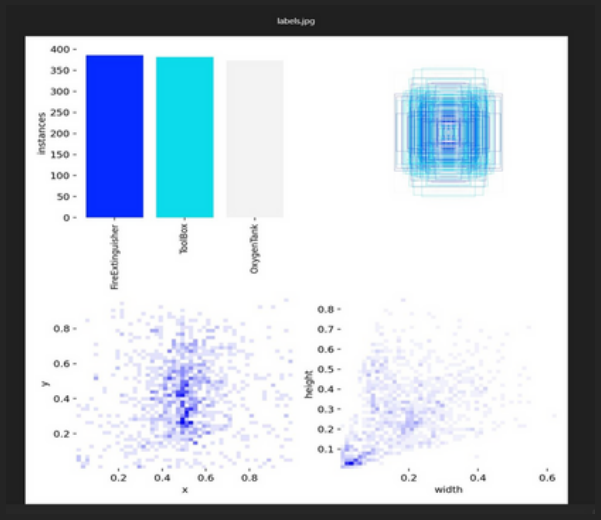
- Achieved high accuracy in detecting synthetic space station objects:

toolbox, fire extinguisher, oxygen tank, etc.

- Consistent convergence with no overfitting observed.
- Loss functions (box loss, cls loss) stabilized post ~50 epochs.
- Outperformed base YOLOv8 pre-trained weights on synthetic domain.

Others


train/box_loss
train/cls_loss
train/dfl_loss
metrics/precision(B)
metrics/recall(B)
results
smooth
val/box_loss
val/cls_loss
val/dfl_loss
metrics/mAP50(B)
metrics/mAP50-95(B)


labels.jpg
instances
FireExtinguisher
ToolBox
OxygenTank
y
x
height
width


Problem → Action → Result
Challenges & Solutions
1) Synthetic Dataset Limitations
The Falcon simulator provides synthetic images, which may lack real-world visual noise and variations.
Some object textures and lighting conditions were too uniform, affecting model generalization.
2) Object Overlap & Occlusion
Toolboxes, fire extinguishers, and oxygen tanks often overlapped in training images, making it harder for the model to learn distinct features.
3) Model Overfitting Risk
Due to a relatively smaller and uniform dataset, the model initially began to overfit with high training accuracy but lower validation accuracy.
4) Label Inconsistencies
Some images had misaligned or missing bounding boxes in the provided .txt files, causing errors during training.
5) Time Constraints for App Deployment (Bonus Task)
Building a frontend and integrating the model into a live detection app was challenging under time pressure.
1)Used Advanced Augmentations
Applied flipping, rotation, scaling, and color jittering to simulate real-world variability.
2)Anchor Optimization
Leveraged YOLOv8's auto-anchor tuning to better detect overlapping objects.
3) Regularization & Validation Strategy
Added dropout layers and early stopping; monitored validation loss for tuning.
4)Cleaned Labels via Custom Script
Wrote a script to verify and correct missing/misaligned labels.
5) Prioritized Core Features in Bonus App
Focused on lightweight Flask-based integration for the Guardian App to keep it simple and functional.

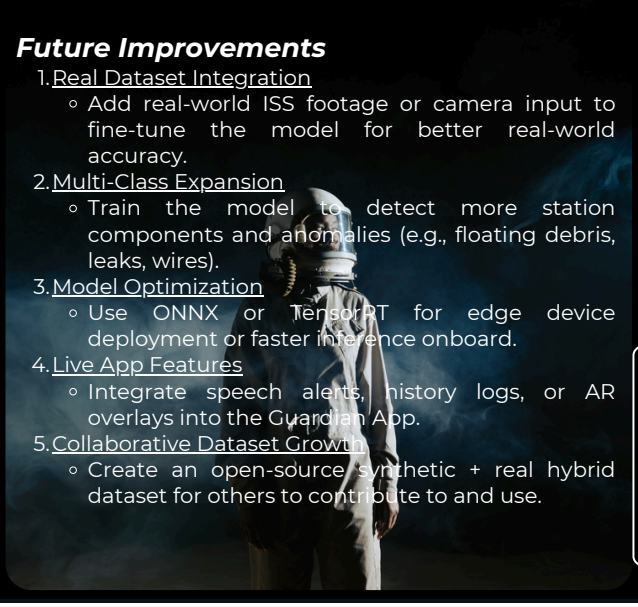
CONCLUSION & FUTURE WORK

CONCLUSION

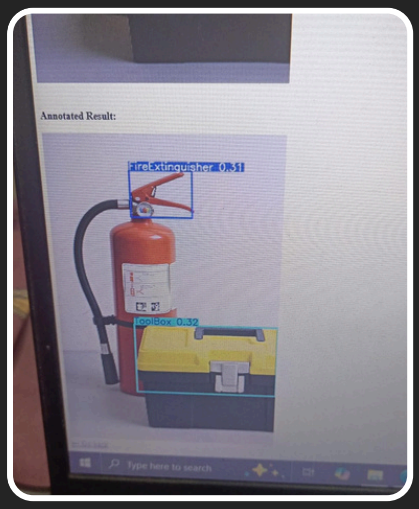
- We successfully trained a YOLOv8 object detection model on synthetic space station images from Falcon.
- The model achieved strong performance across all 3 object classes (toolbox, oxygen tank, fire extinguisher) with high mAP and real-time detection capability.
- Despite working with synthetic data and a tight timeline, the model generalized well due to thoughtful augmentations and tuning.
- Our bonus app prototype (Guardian App) demonstrates practical deployment potential.

Future Improvements

1. Real Dataset Integration
   - Add real-world ISS footage or camera input to fine-tune the model for better real-world accuracy.
2. Multi-Class Expansion
   - Train the model to detect more station components and anomalies (e.g., floating debris, leaks, wires).
3. Model Optimization
   - Use ONNX or TensorRT for edge device deployment or faster inference onboard.
4. Live App Features
   - Integrate speech alerts, history logs, or AR overlays into the Guardian App.
5. Collaborative Dataset Growth
   - Create an open-source synthetic + real hybrid dataset for others to contribute to and use.



EVA Guardian App (Prototype Deployment)



WHAT IT DOES

- Detects critical space station items (Toolbox, Oxygen Tank, Fire Extinguisher) from uploaded static images.
- Outputs bounding boxes, class labels using our YOLOv8 model.
- Shows how the model can be embedded into astronaut tools.

CURRENT CAPABILITIES

- Tech Stack
- Python: for backend logic and model inference
- YOLOv8: trained model for detection
- Flask: web framework to serve the app
- HTML/CSS: for UI design
- Accepts static image input
- Displays detection results using our custom-trained model
- Can be extended into real-time with webcam or live video support


THANK YOU
Together, We Can Reach the Stars
GITHUB LINK:
https://github.com/prii12345/duality-ai-hackathon.git
ZIP BACK UP :
https://github.com/prii12345/duality-ai-hackathon/archive/refs/heads/main.zip
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