Confidential - Do not share

Multi-sensor rail track detection in automatic train operations

Master's thesis in Data Science

Student: Attila Kovacs

1st Advisor: Lukas Rohatsch (UAS Technikum Wien)

2nd Advisor: Daniele Capriotti (M2C Expert Control GmbH)

Alignment: 30.04.2024

FH University of Applied Sciences TECHNIKUM WIEN

Outline

- Motivation
- Datasets
- Solution approach
  - Traditional approach – Fast line detection
  - Deep learning approach – YOLOv8
- Results
- Conclusion

Motivation

Automatic train operations (ATO)

- ATO systems use advanced technologies to perceive and interpret the railway environment to facilitate autonomous operations with minimal human intervention

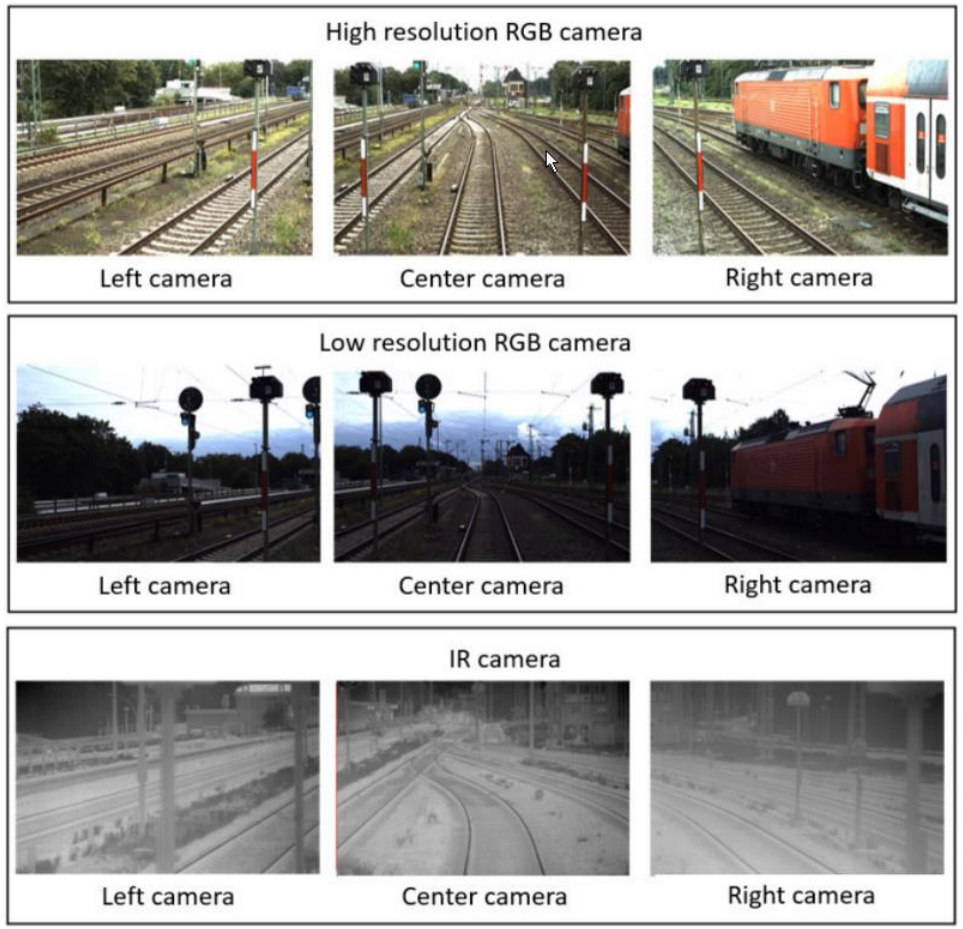
Automatic rail track detection

- Computer vision-based rail track detection is a crucial component for autonomous train navigation as it enables trains to understand and navigate complex rail networks with minimal human intervention

Motivation

Input: images generated by different sensors mounted on locomotive

Goal: identify and segment rail tracks



FH University of Applied Sciences TECHNIKUM WIEN

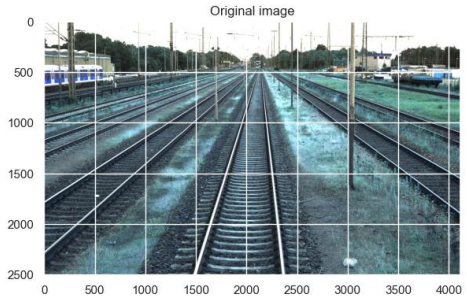
Dataset

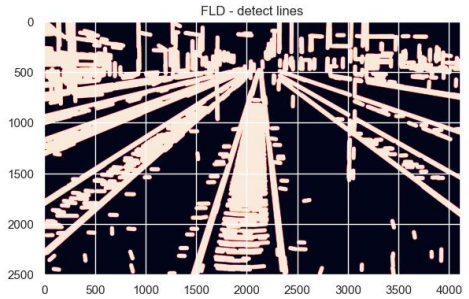
- OSDaR23 dataset (Digitale Schiene / Deutsche Bahn) → **Training and evaluation**
  - 7.421 frames from 45 video sequences
  - 27.386 labels
  - Low/high resolution RGB camera and infrared camera
- RailSem19 dataset (Austrian Institute of Technology) → **Training**
  - 8.500 images
  - 58.483 labels
  - Only RGB images
- Video stream (M2C / DB Cargo) → **Evaluation**
  - 1:14h video
  - Different scenarios such as tunel, double/single track, side walls etc.

Solution approach

- **Non-AI-based segmentation with fast line detection**
  - Detect edges in image
  - Extract line segments
  - Grouping of line segments based on orientation and proximity
- **Deep-learning based approach based on YOLOv8**
  - Train model with pre-labeled images
  - Classify each pixel in an image according to its category (rail tracks vs. background)
  - Convert pixels into polylines
- **Evaluation criterion**
  - Dice score – best suited for unbalanced datasets, e.g., when the background is dominant

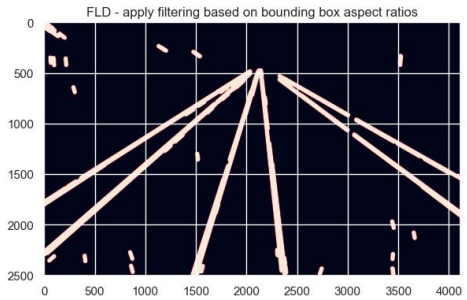
Non-AI-based segmentation with fast line detection (FLD)

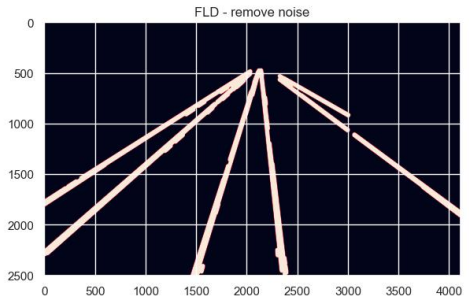




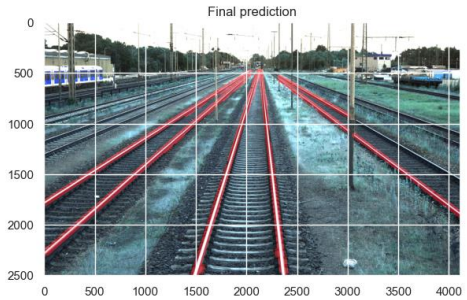
Apply FLD

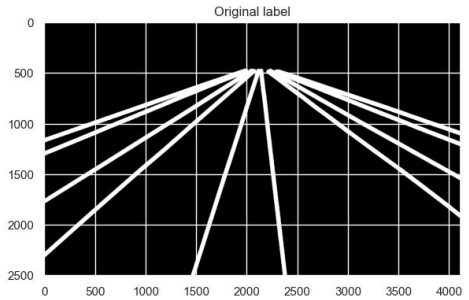
Filtering by removing „unusual“ lines





Removing noise based on clustering



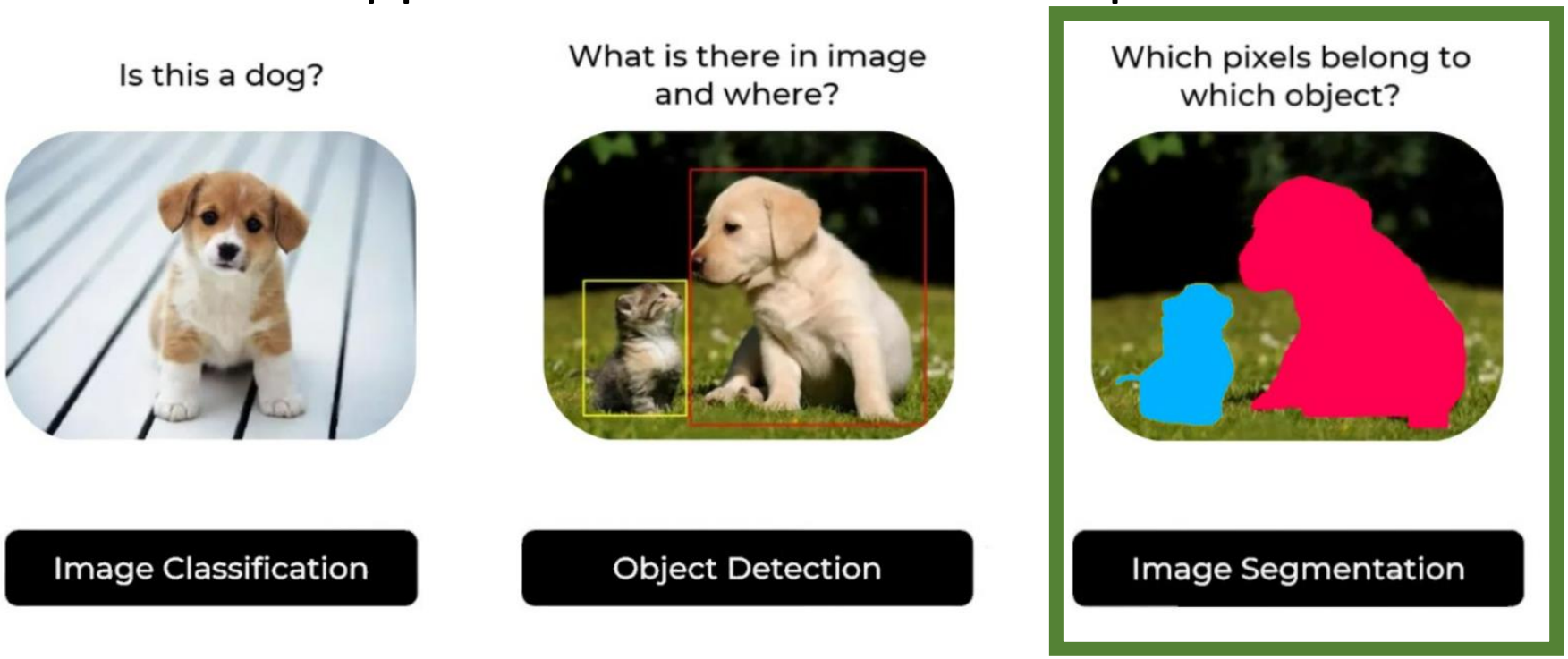


Labels are given in the dataset

FH University of Applied Sciences TECHNIKUM WIEN

Deep-learning based approach based on YOLOv8

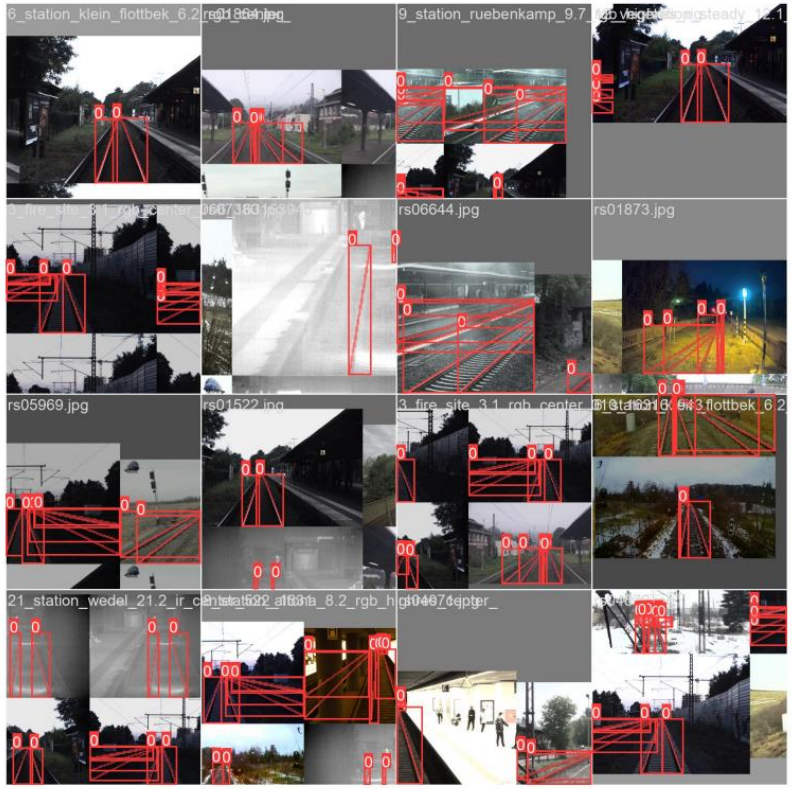
There are differenet applications in AI-based computer vision



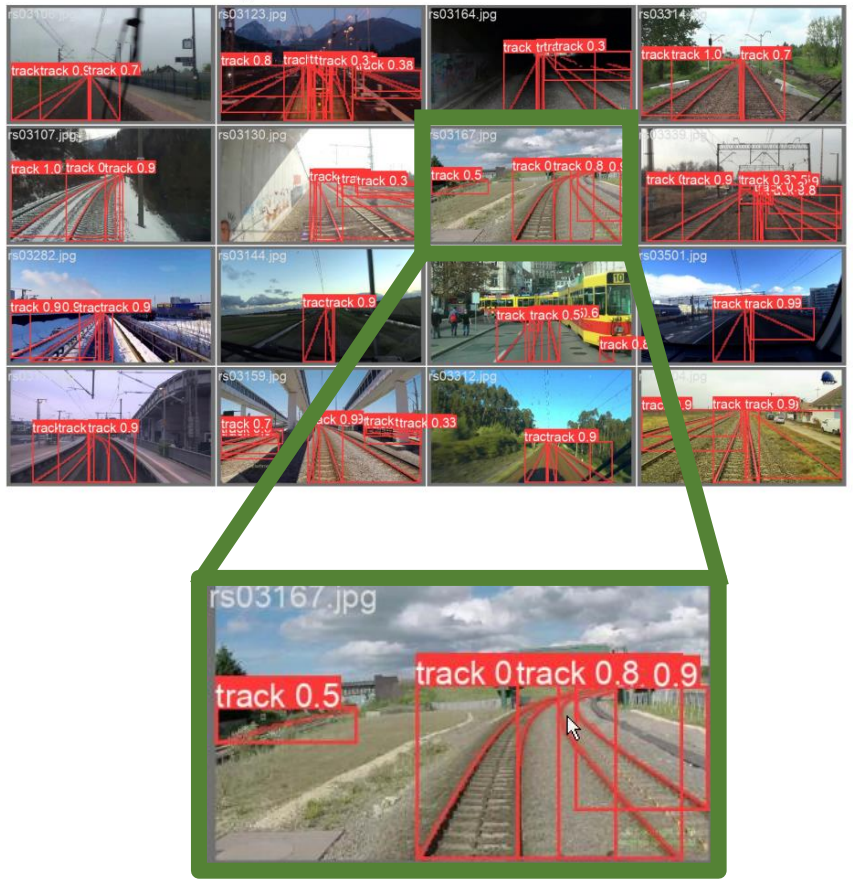
FH University of Applied Sciences TECHNIKUM WIEN

Deep-learning based approach based on YOLOv8

In each step of the training process, the model is provided with labeled images



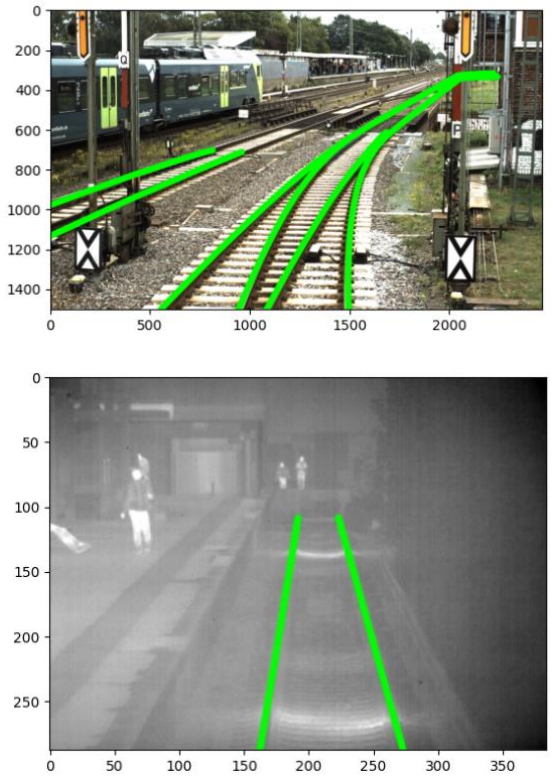
The model is evaluated on images from the validation set



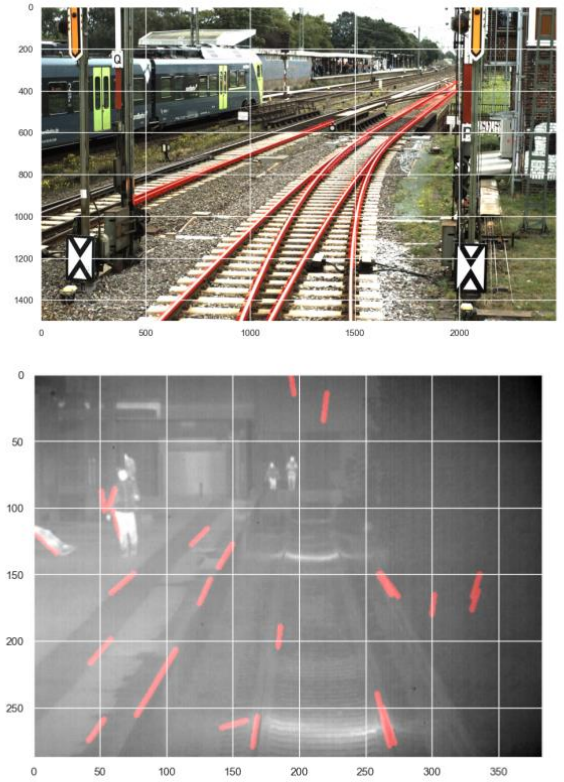
FH Universi Applied TECHN WIEN

Results – Visual inspection

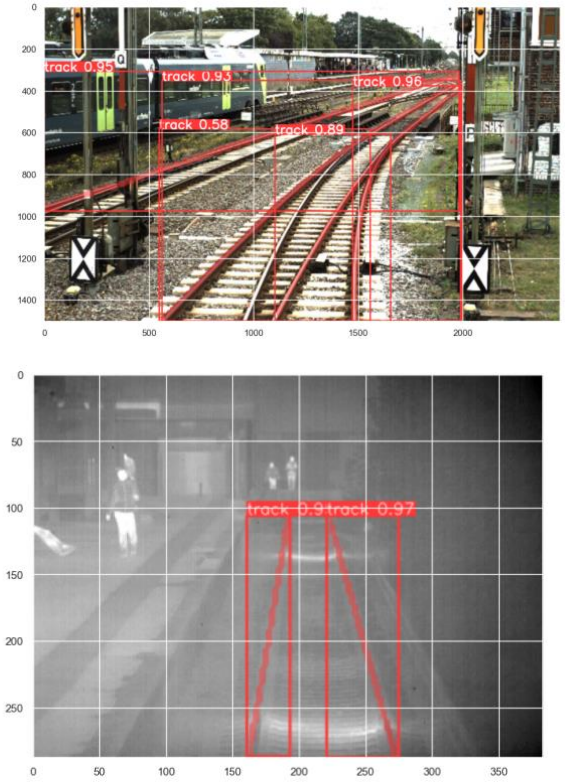
Ground truth



FLD

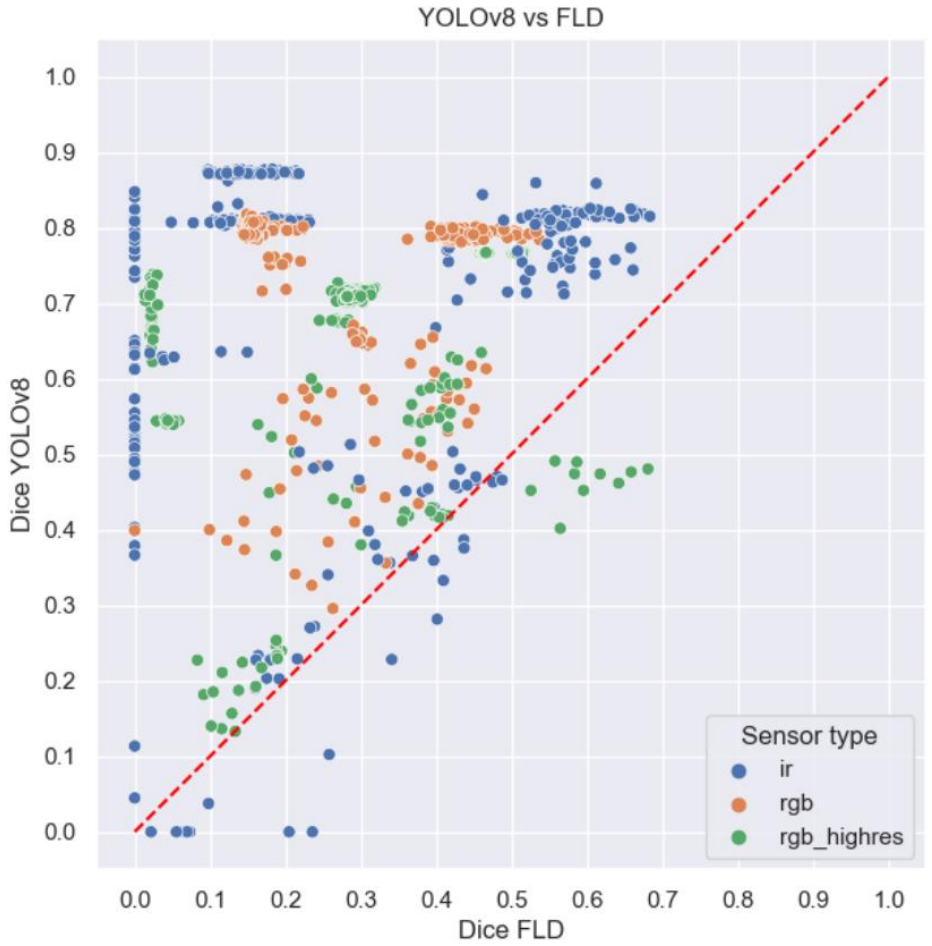


YOLO



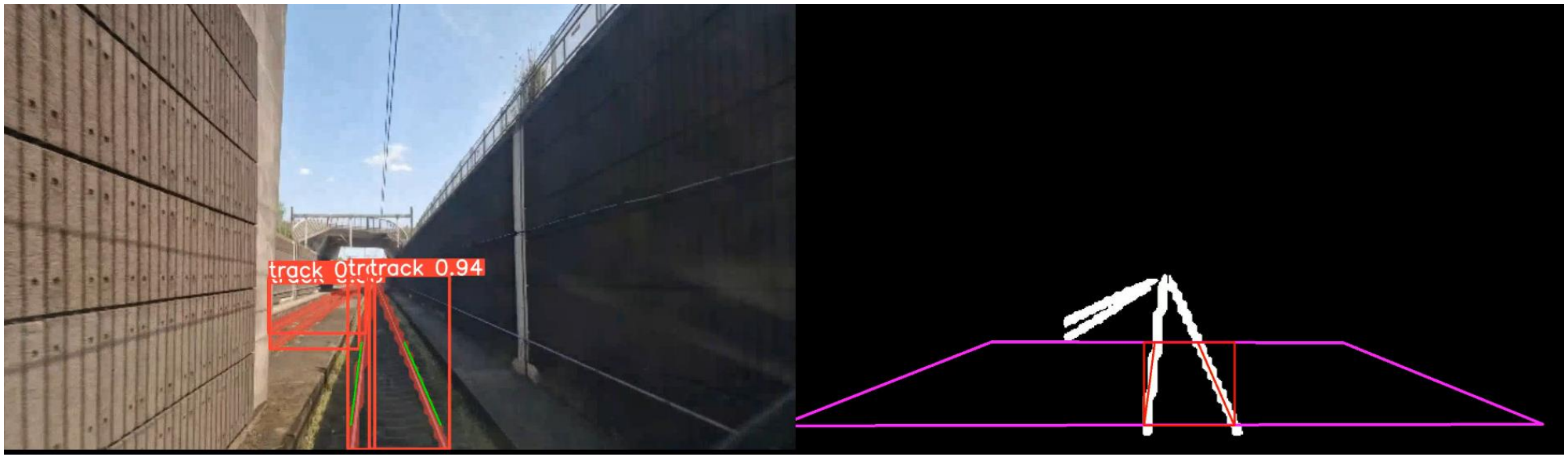
FH University of Applied Sciences
TECHNIKUM WIEN

Results – FLD vs. YOLOv8 on OSDaR23



FH University of Applied Sciences TECHNIKUM WIEN

Results – Video stream: incorportating domain knowledge



Conclusion

- First project to investigate different sensor types in rail track detection
- Devised traditional base-line approach (FLD) and AI-based approach (YOLO)
- YOLO outperforms FLD in almost all test images based on Dice-score
- YOLO seems to provide very good results on infrared images
- **Best performace is achieved if AI-based track detection is enhanced by domain knowledge**

Thank you for the data/video and the attention!

FH University of Applied Sciences TECHNIKUM WIEN