Vision-Based Anomaly Detection for Railroad Systems

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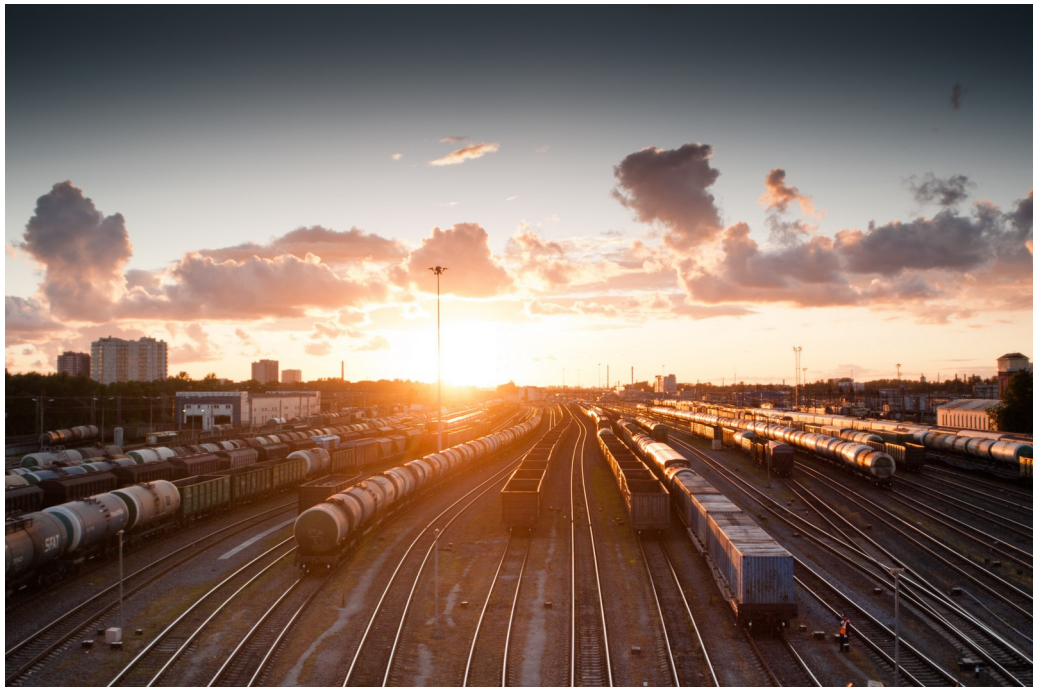
Background

Railroad transportation

- Essential gear for urbanized society and economy
- One key element in tackling the climate crisis

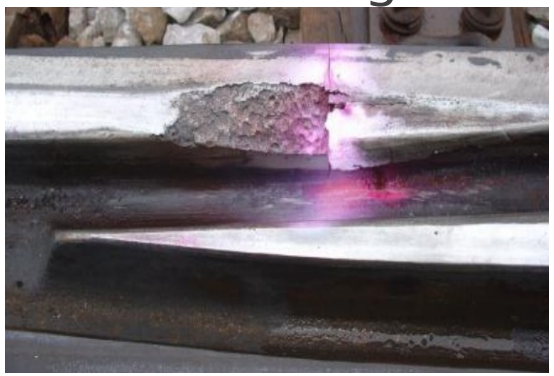
Safety and reliability

- Meticulous infrastructure maintenance
- Essential to avoid breakdowns and accidents
- Automizing inspection is interesting

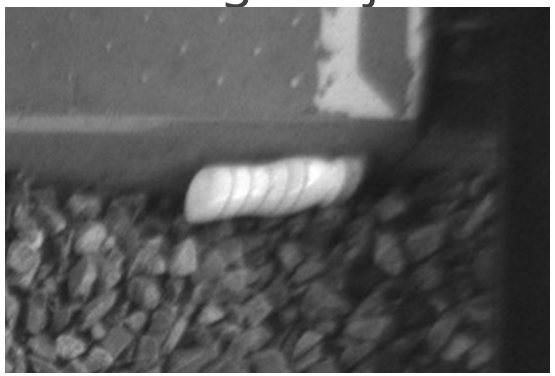


Problems

Rail damages

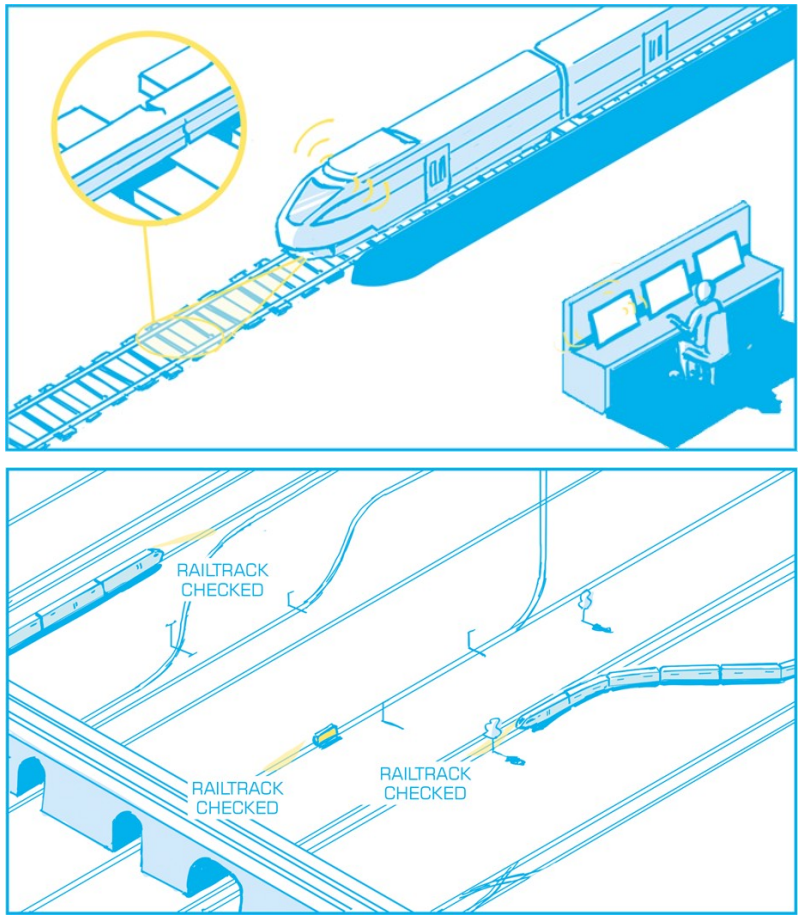


Foreign objects

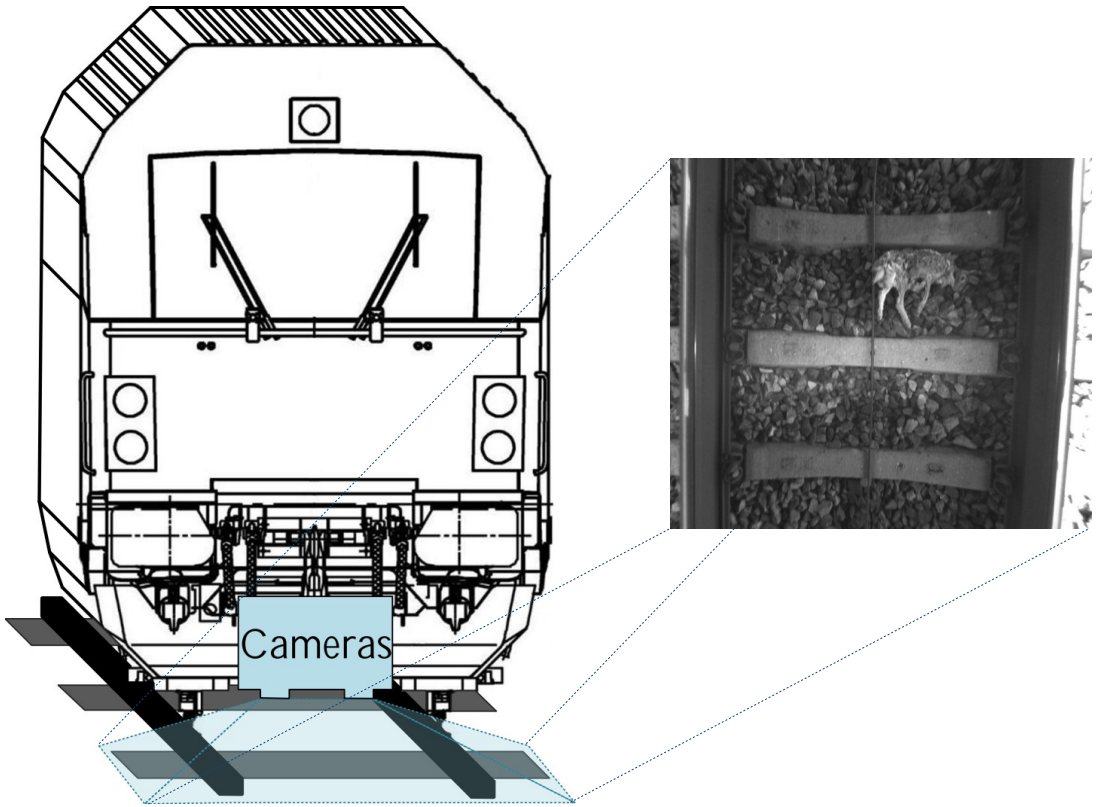


Heavy vegetation

Motivation and Goals



Vision-Based Anomaly Detection System



My Work (Software)

Vision-Based Anomaly Detection Algorithm for Railroad Systems

(VADAR)

Anomaly? Yes/No

Autoencoders (AEs)

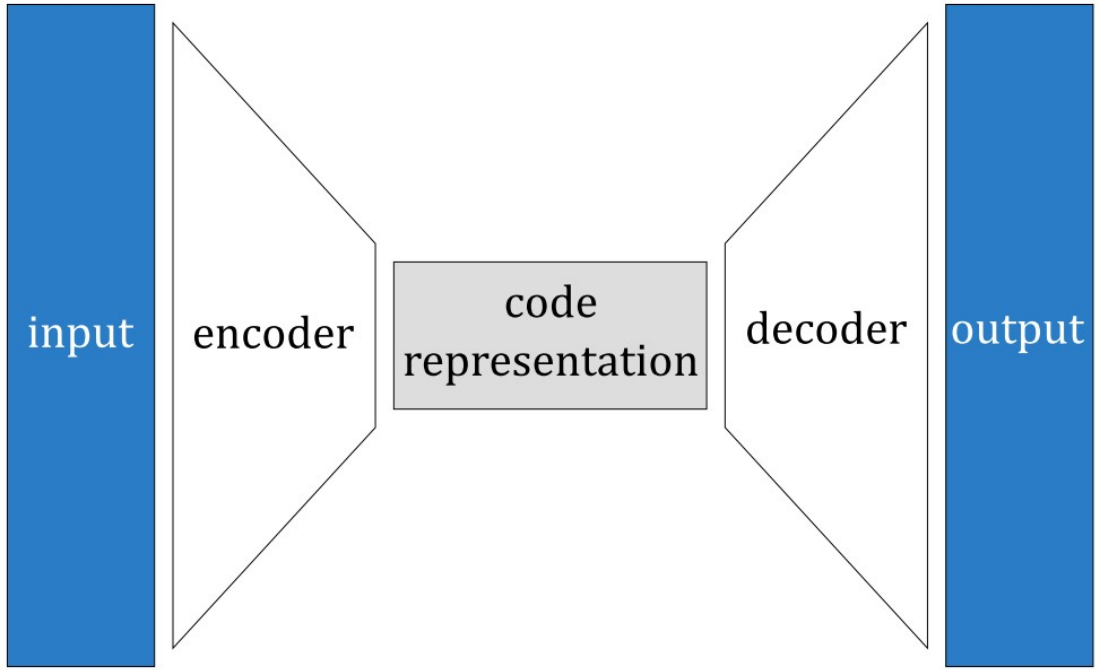
Neural Network-based approach

Training:

- „Output = Input“
- Anomaly Detection: Training without anomalies
- Extracting features from data (encoder)
- Reconstruction from code (decoder)

Enables anomaly localization

- Regions of high reconstruction errors



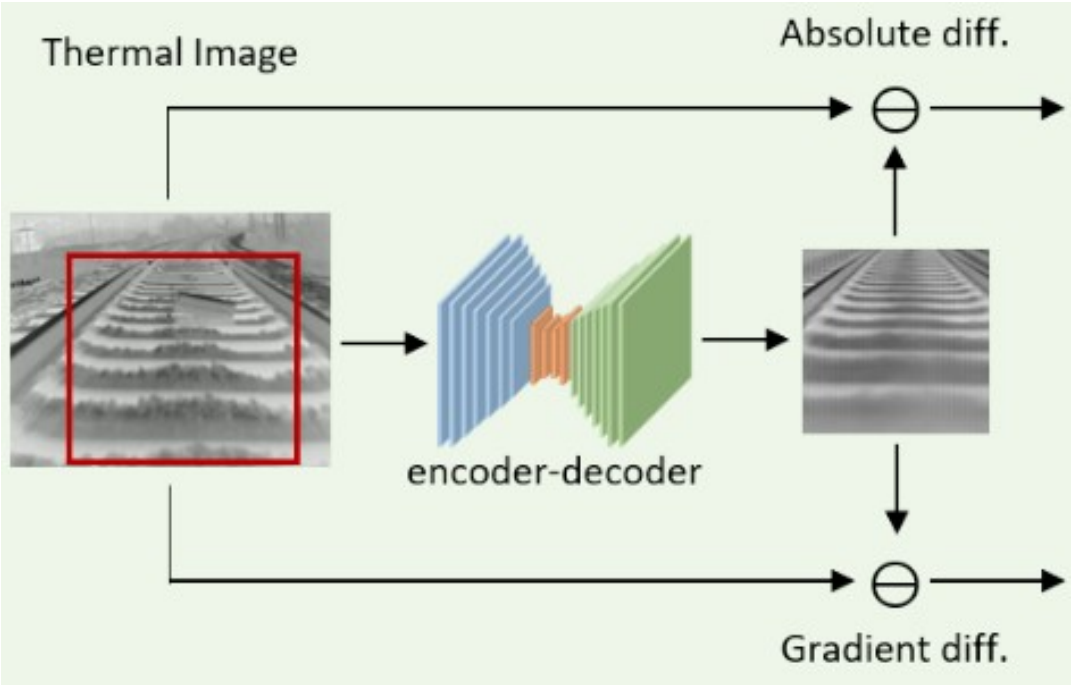
Anomaly Detection (State-of-the-Art)

Autoencoder approach, similar to Gasparini et al [1]

- Supervised approach
- Reconstruction error is analyzed
- Focused on large construction tools
- Infrared cameras (during the night)
- Front-view perspective

We want to detect smaller objects and rail damages

Monochromatic camera, birds-eye view perspective



[1] Gasparini, Riccardo, et al. "Anomaly Detection, Localization and Classification for Railway Inspection." 25th International Conference of Pattern Recognition. 2020

VADAR

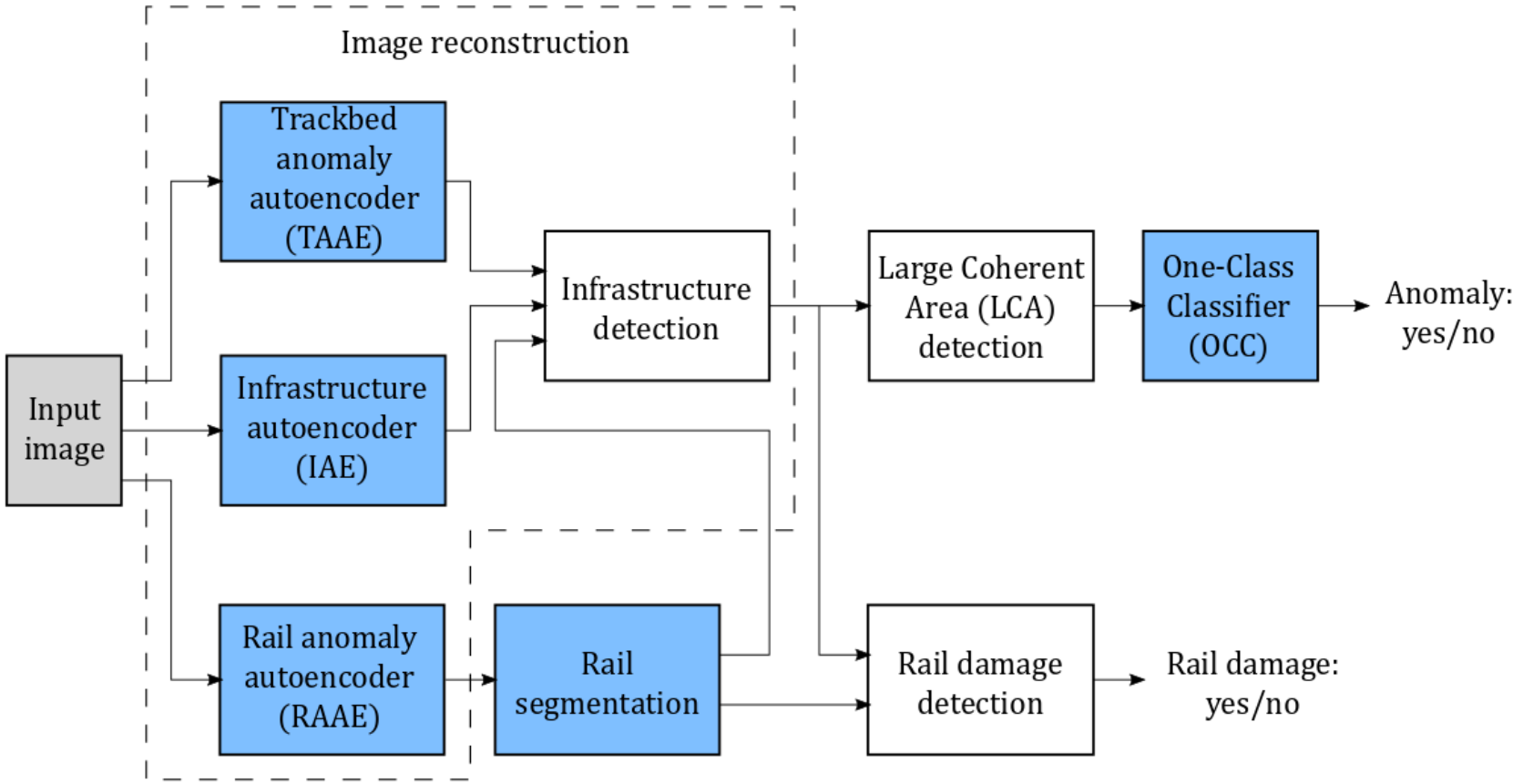
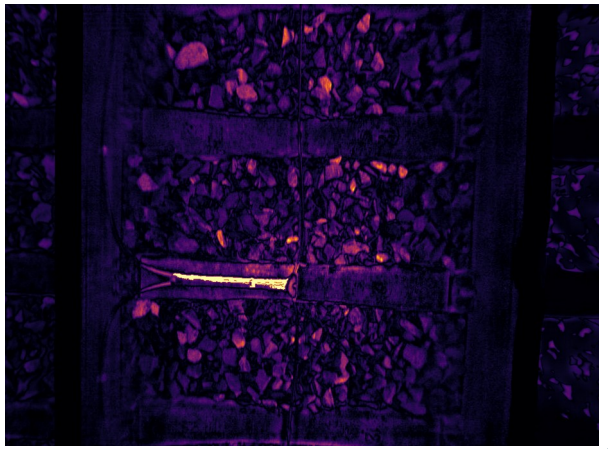
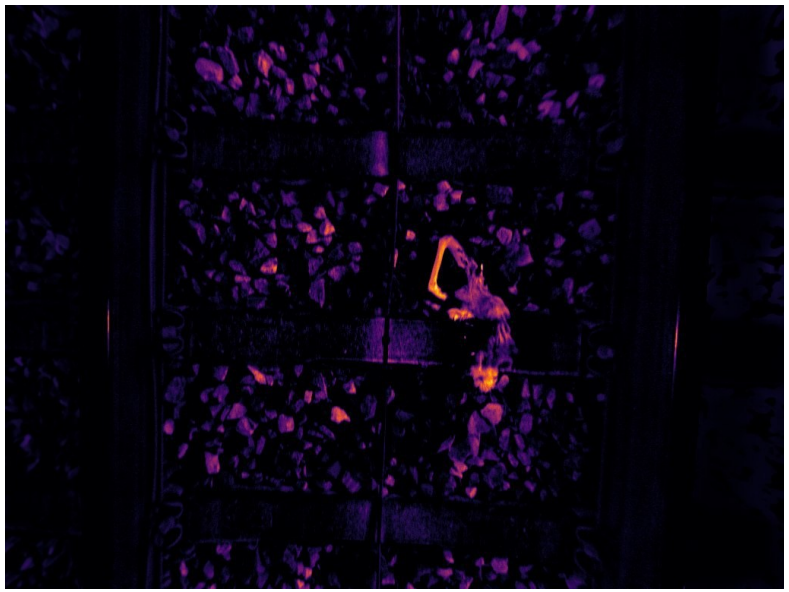


Image reconstruction
Trackbed anomaly autoencoder (TAAE)
Infrastructure autoencoder (IAE)
Input image
Infrastructure detection
Large Coherent Area (LCA) detection
One-Class Classifier (OCC)
Anomaly: yes/no
Rail anomaly autoencoder (RAAE)
Rail segmentation
Rail damage detection
Rail damage: yes/no



Trackbed Anomaly Detection

Original input image



Reconstruction error image
„|input – output|“

Detected Large Coherent Area (LCA)

Metrics

Accuracy:	$\frac{\#\text{ Correct Cases}}{\#\text{ Total cases}}$	Probability of correct cases
False Positive Rate (FPR):	$\frac{\#\text{ False Positives}}{\#\text{ Total Negatives}}$	Probability of False Alarms
Recall:	$\frac{\#\text{ True Positives}}{\#\text{ Relevant Cases}}$	Probability of Correct Detection

Algorithm to Detect Dogs

11 Dogs
3 Cats

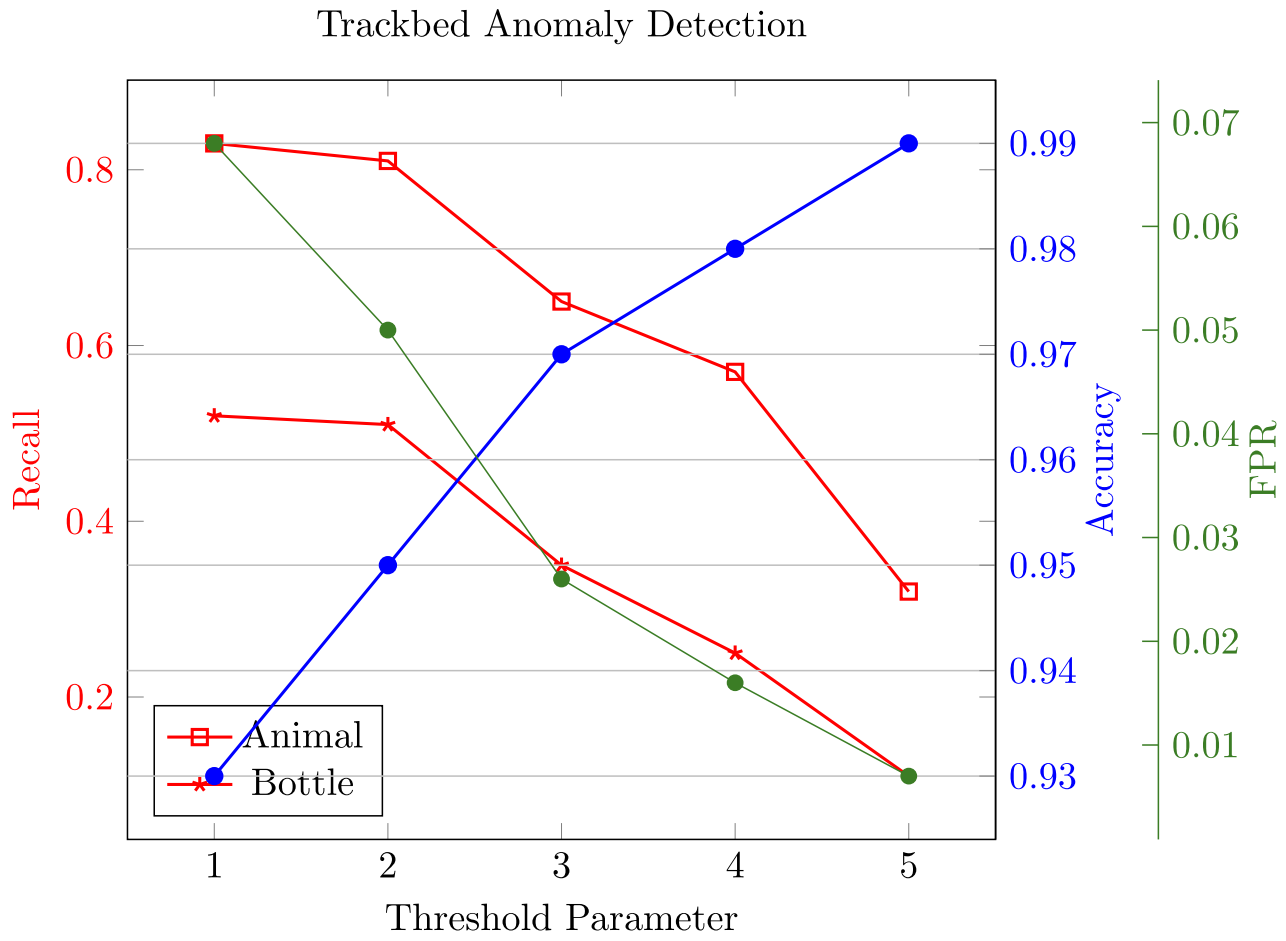
The algorithm detects 9 dogs correctly and 1 cat incorrectly as a dog

$$\text{Accuracy: } \frac{\#\text{ Correct Cases}}{\#\text{ Total cases}} = \frac{11}{14} = 0.79$$

$$\text{FPR: } \frac{\#\text{ False Positives}}{\#\text{ Total Negatives}} = \frac{1}{3} = 0.33$$

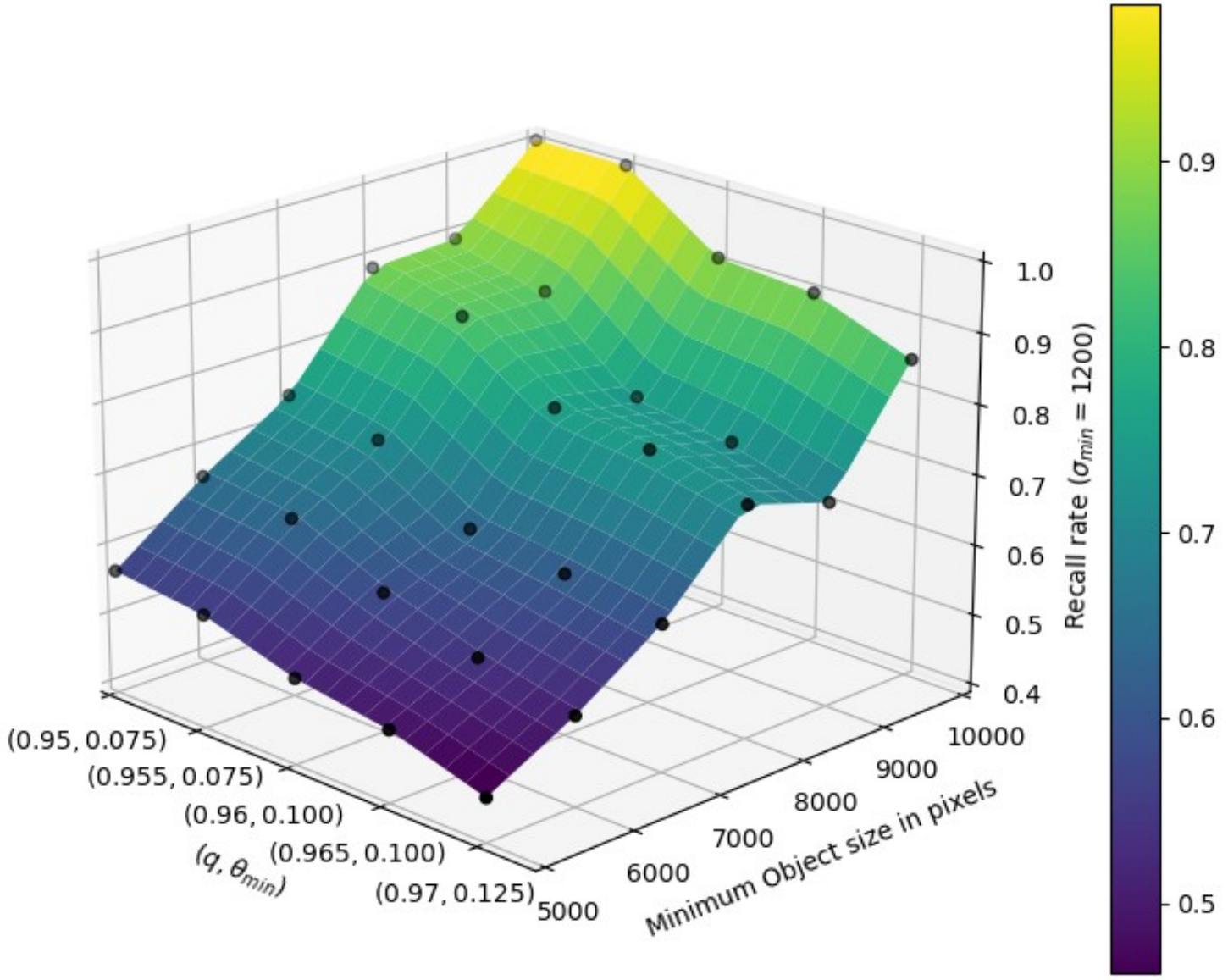
$$\text{Recall: } \frac{\#\text{ True Positives}}{\#\text{ Relevant Cases}} = \frac{9}{11} = 0.82$$

Trackbed Anomaly Detection



Trade-off between Recall and FPR

Trackbed Anomaly Detection



Rail Damage Detection

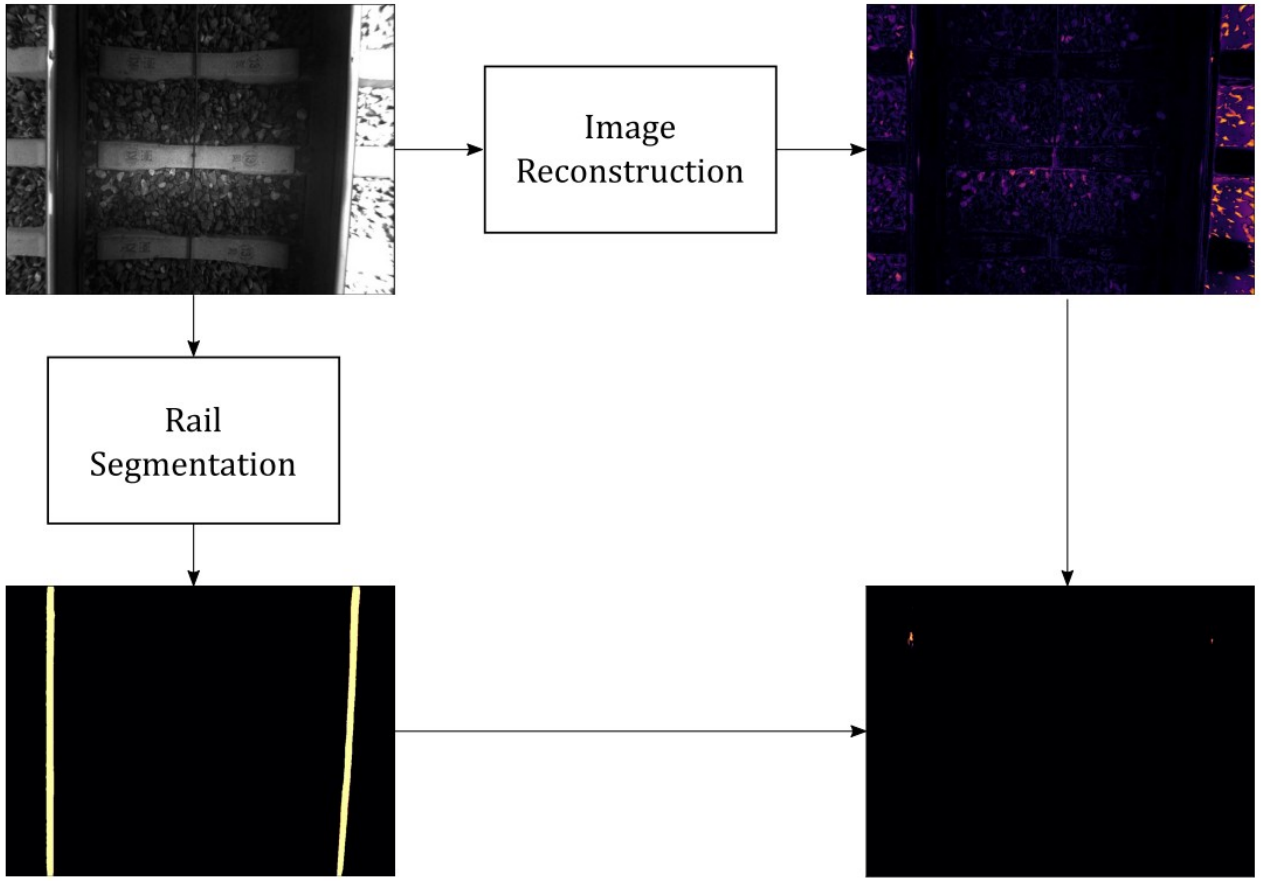
Image Reconstruction

- Rail Anomaly Autoencoder (RAAE)

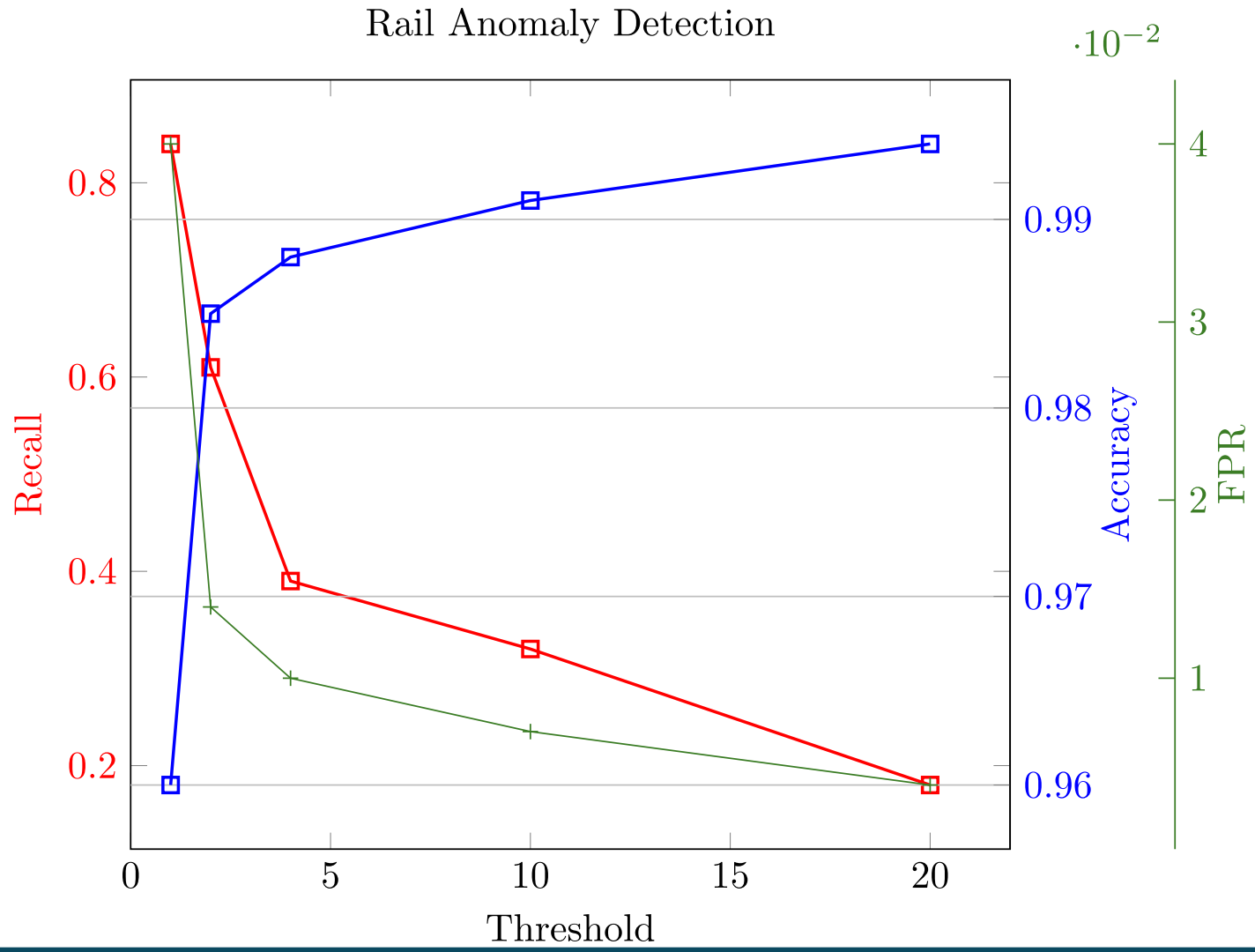
Rail Segmentation

- Focus on rail heads
- Ignore rest of the trackbed

Summed-up absolute reconstruction error as anomaly indicator



Rail Anomaly Detection



Summary

- VADAR is a ML algorithm that visually
  - Detects anomalies in the trackbed
  - Detects anomalies on the rail
- Scope:
  - Top down view
  - Limited dataset
  - Limited Set of anomalies
  - Unknown performance in real setting

- Future Work:
  - Cabin view
  - Larger and more diverse dataset
  - More and more diverse set of anomalies
  - Other ML algorithms

Thank You For Your Attention