

# 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

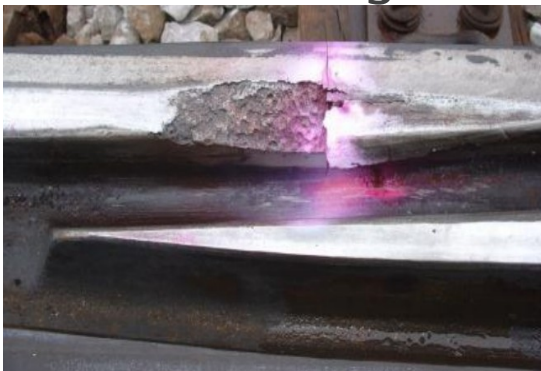
## Safety and reliability

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



# Problems

Rail damages



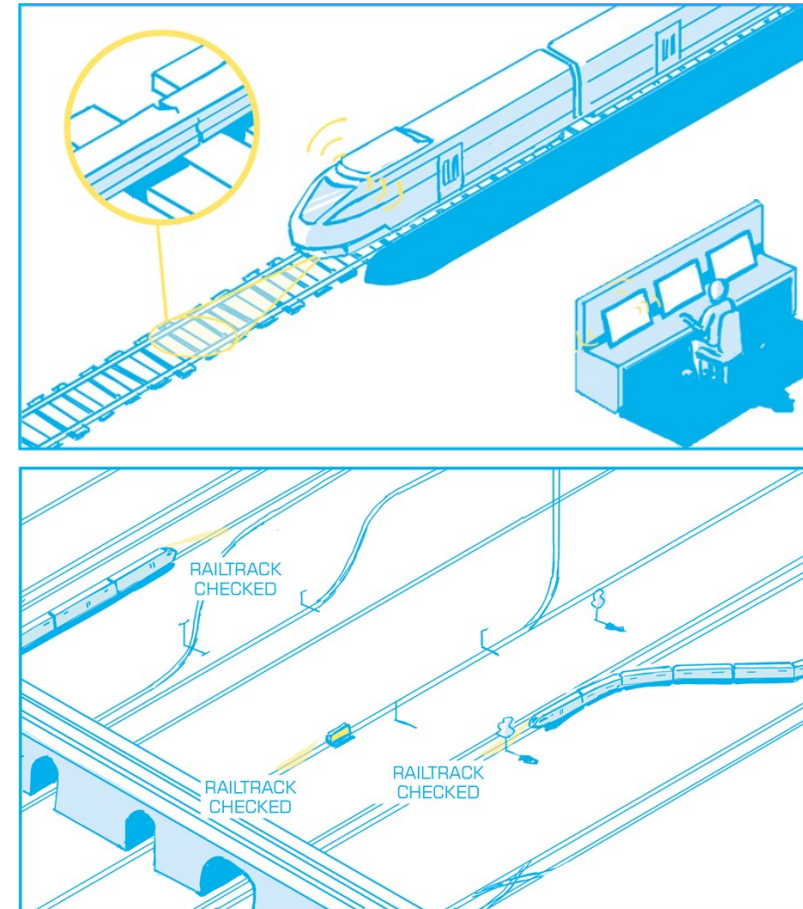
Foreign objects



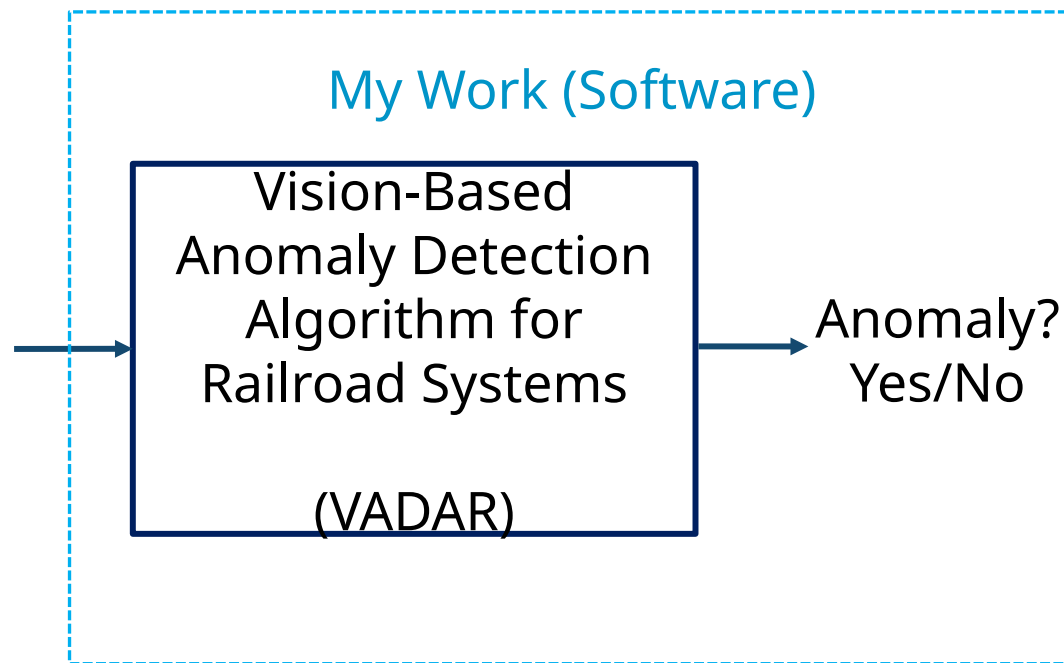
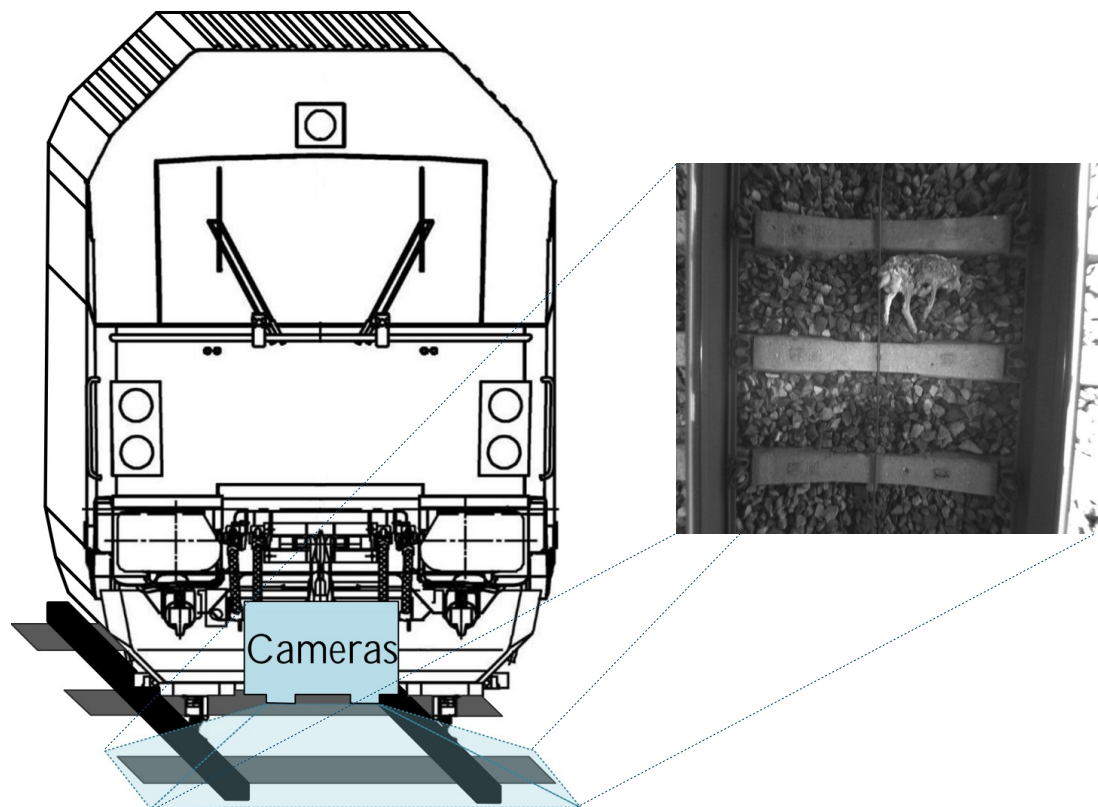
Heavy vegetation



# Motivation and Goals



# Vision-Based Anomaly Detection System



# Autoencoders (AEs)

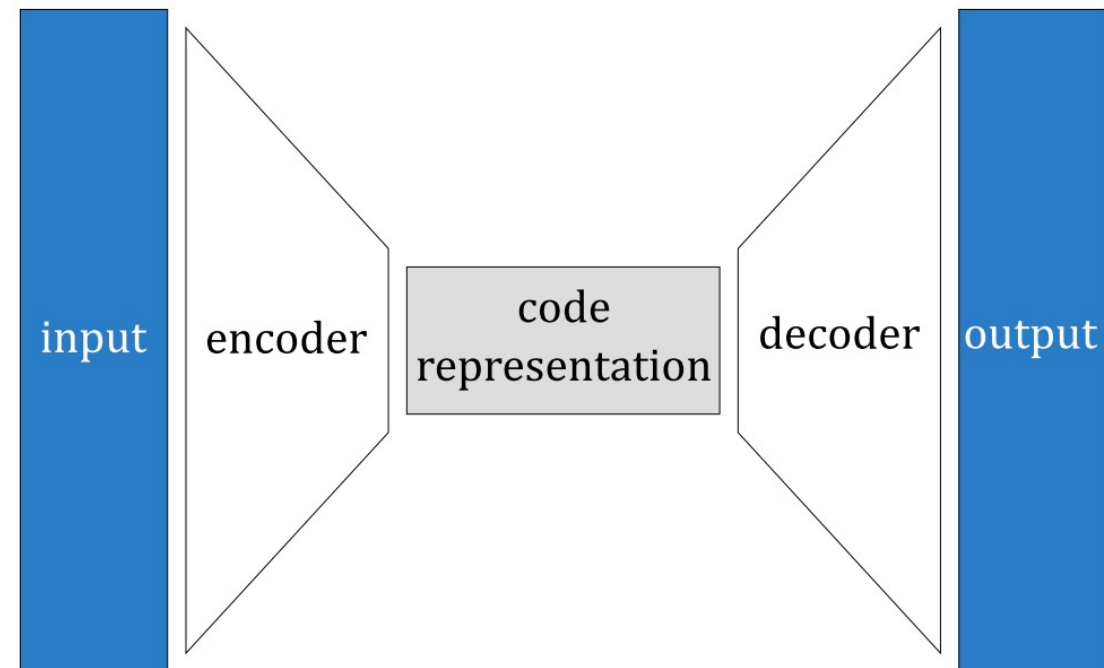
Neural Network-based approach

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



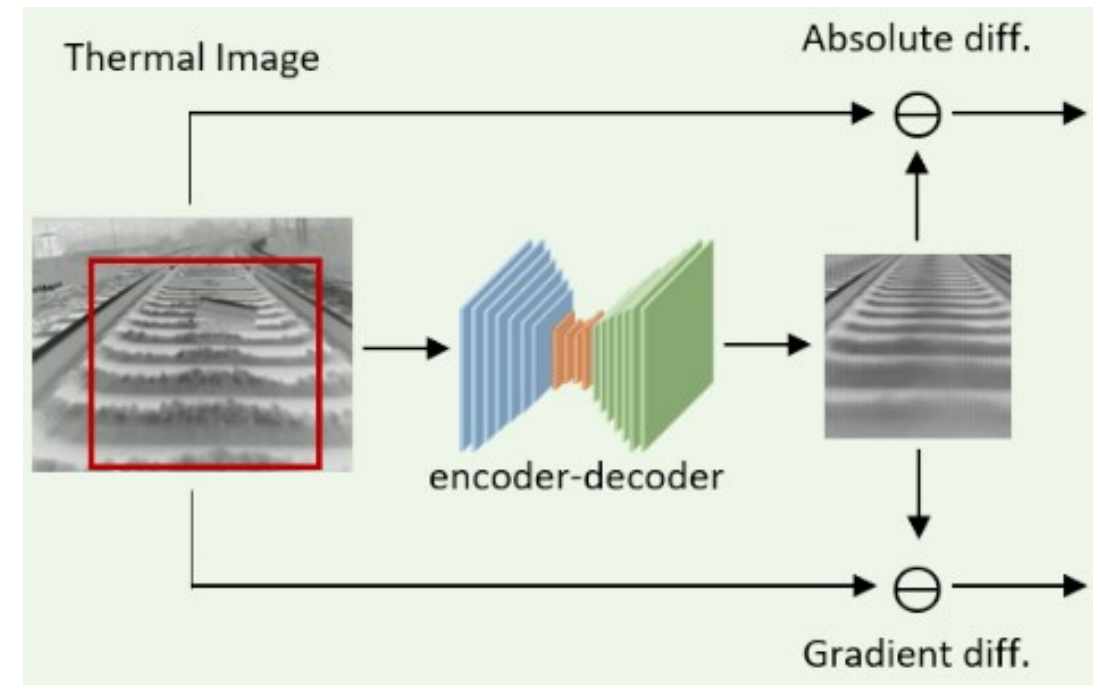
# Anomaly Detection (State-of-the-Art)

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

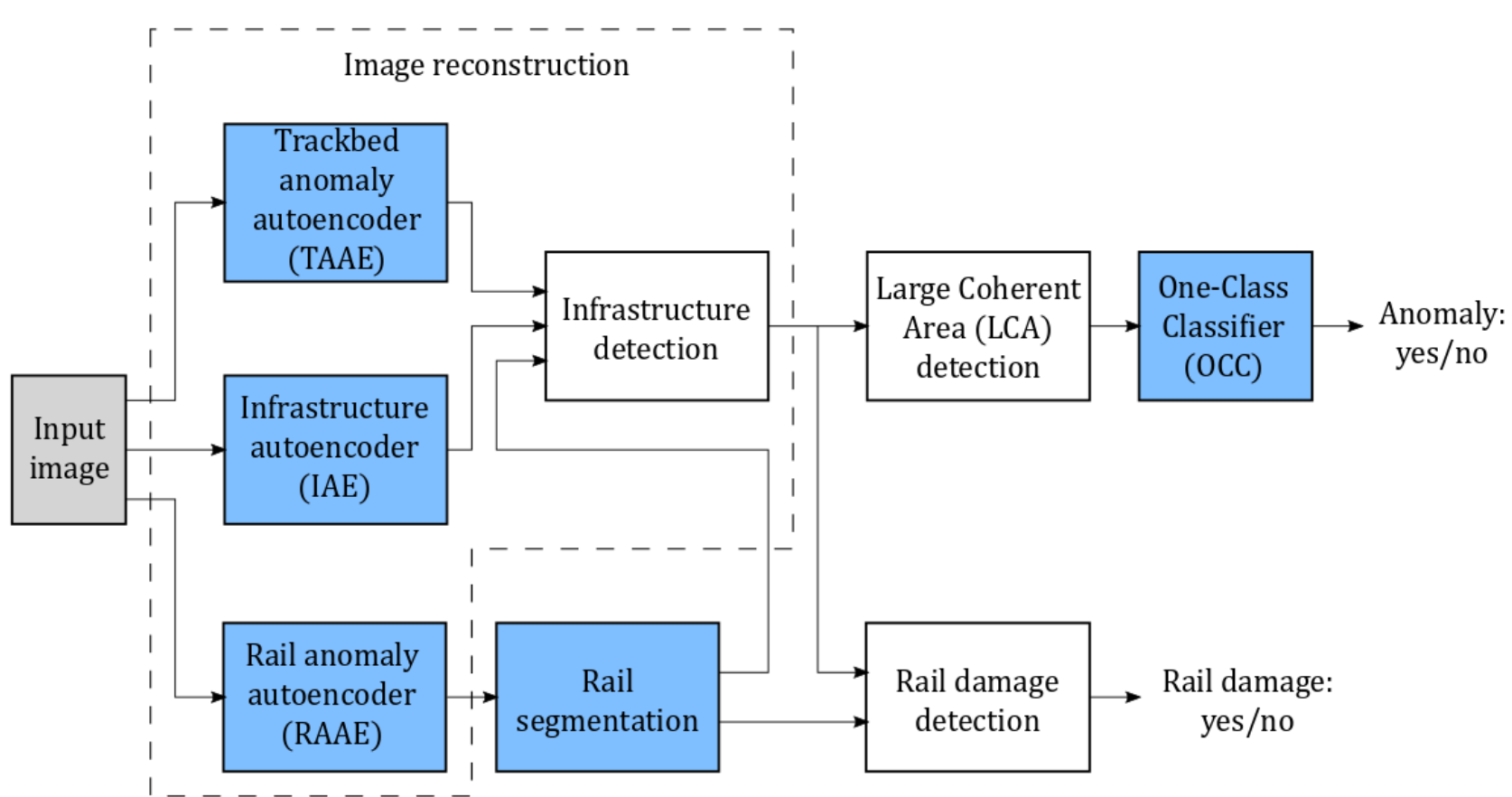
We want to detect smaller objects and rail damages

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

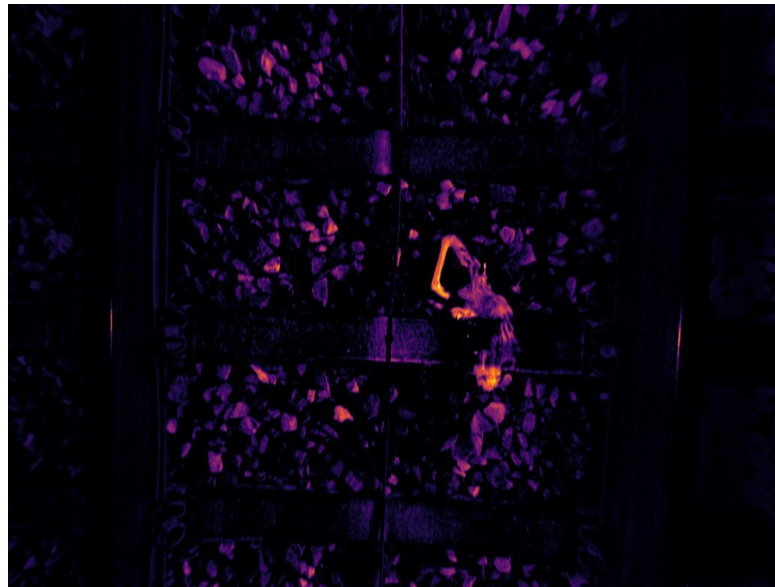




# Trackbed Anomaly Detection



Original input image



Reconstruction error image  
„|input - output|“



Detected Large Coherent Area  
(LCA)

# Metrics

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

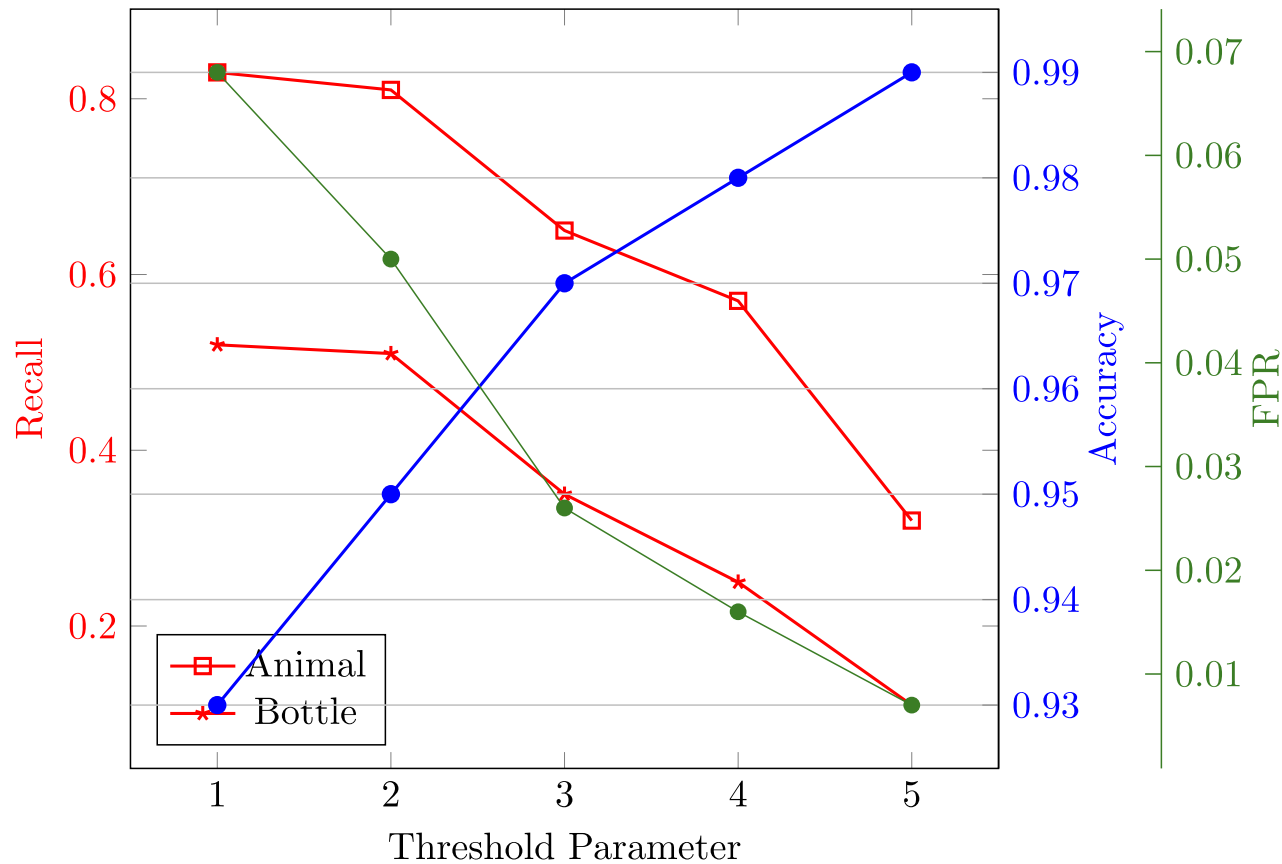
$$\text{Accuracy: } \frac{\# \text{ Correct Cases}}{\# \text{ Total cases}} = \frac{11}{14} = 0.79$$

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

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

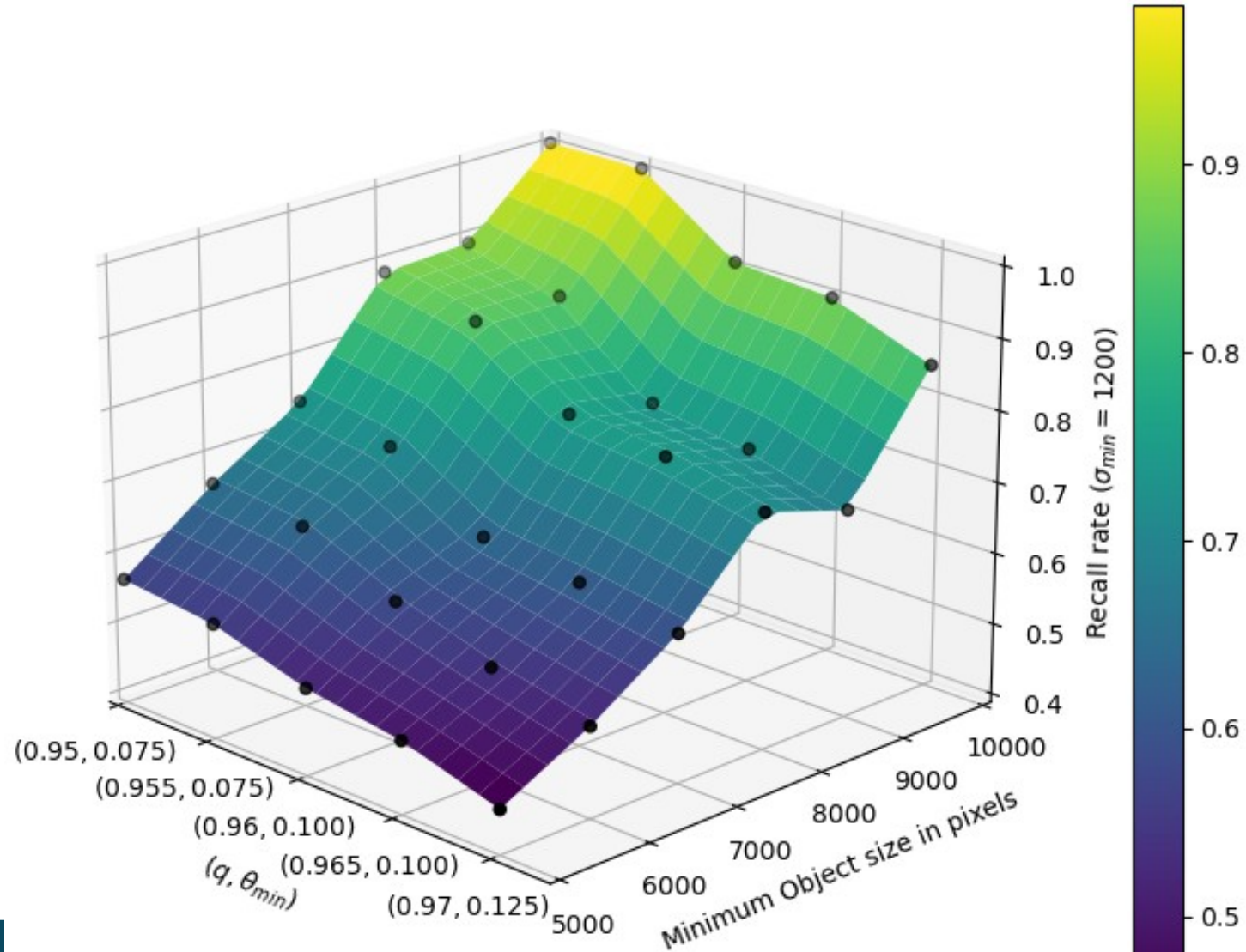
# Trackbed Anomaly Detection

Trackbed Anomaly Detection



Trade-off between Recall and FPR

# Trackbed Anomaly Detection



# Rail Damage Detection

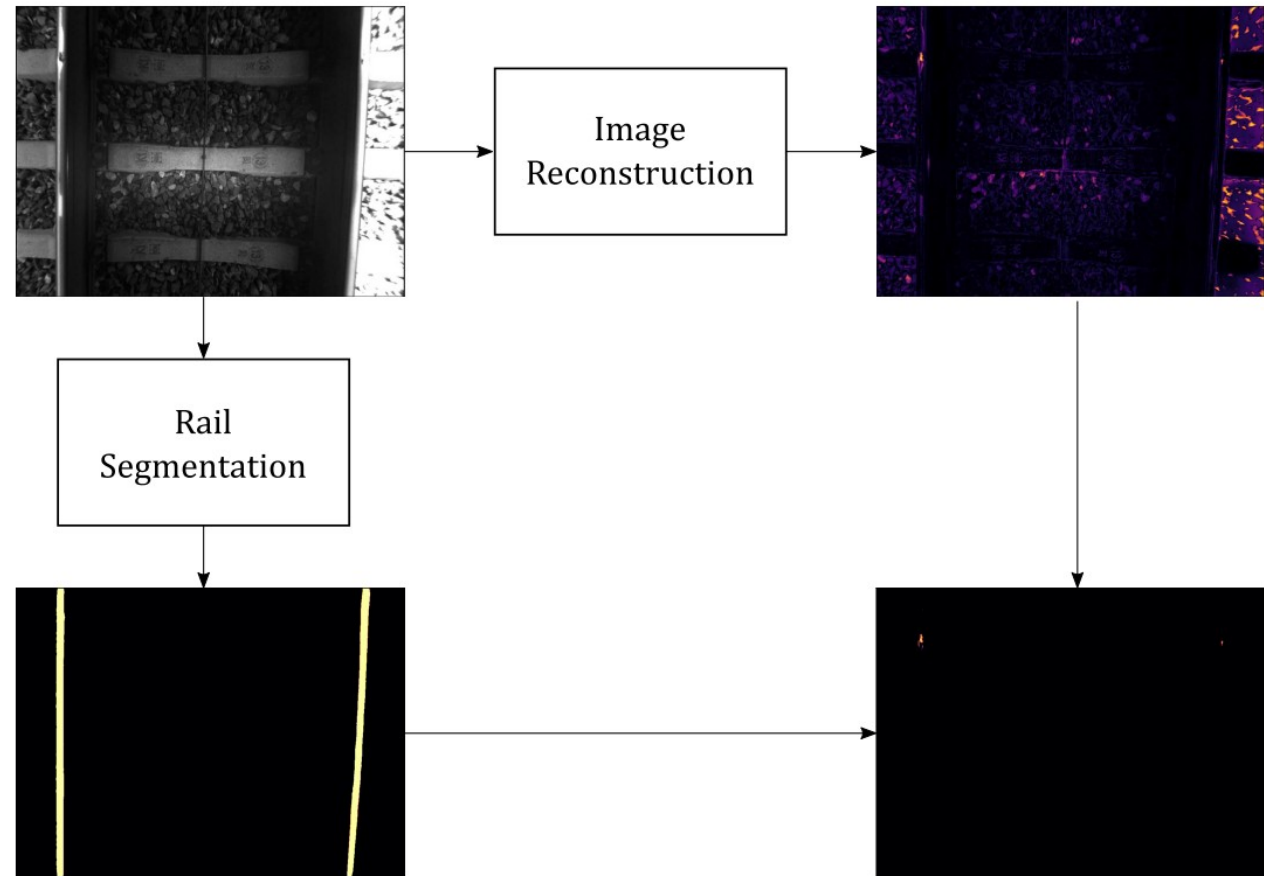
## Image Reconstruction

- Rail Anomaly Autoencoder (RAAE)

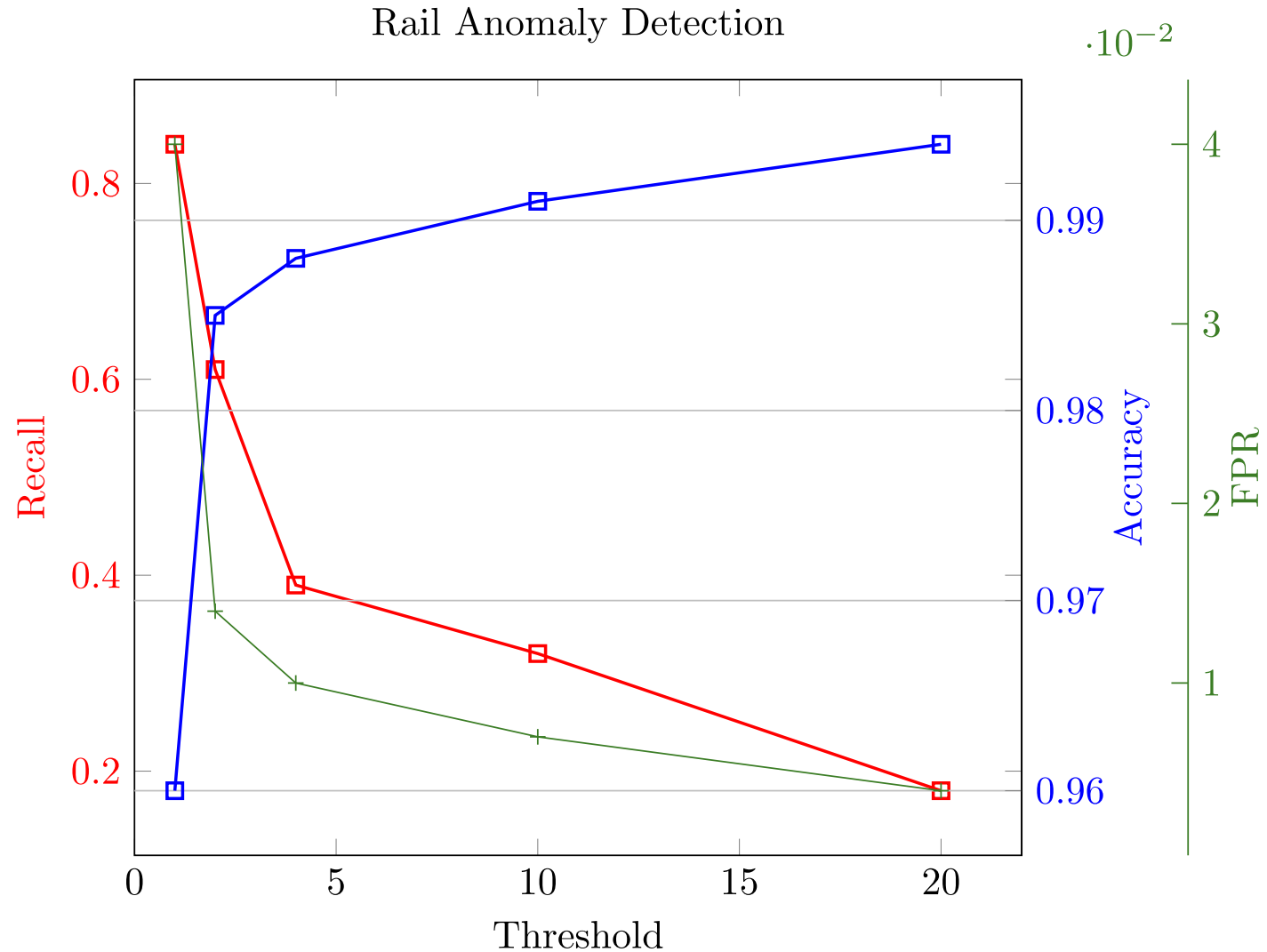
## Rail Segmentation

- 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

