FACULTY OF APPLIED SCIENCES
UNIVERSITY
OF WEST BOHEMIA

DEPARTMENT OF
COMPUTER SCIENCE
AND ENGINEERING

Computer Vision Applications in Video Recordings for Traffic Signal Detection and Classification on Czech Railways

Daniel Schnurpfeil

FACULTY OF APPLIED SCIENCES
UNIVERSITY
OF WEST BOHEMIA

DEPARTMENT OF
COMPUTER SCIENCE
AND ENGINEERING

Computer Vision Applications in Video Recordings for Traffic Signal Detection and Classification on Czech Railways

Bc. Daniel Schnurpfeil

Citation in the bibliography/reference list:
SCHNURPFEIL, Daniel. *Computer Vision Applications in Video Recordings for Traffic Signal Detection and Classification on Czech Railways*. Pilsen, Czech Republic, 2025. Master's Thesis. University of West Bohemia, Faculty of Applied Sciences, Department of Computer Science and Engineering. Thesis advisor Ing. Pavel Mautner, Ph.D.

ZÁPADOČESKÁ UNIVERZITA V PLZNI
Fakulta aplikovaných věd
Akademický rok: 2024/2025

Studijní program: Informatika a její specializace
Forma studia: Prezenční
Specializace/kombinace: Zpracování přirozeného jazyka (ZPJ18np)

Podklad pro zadání DIPLOMOVÉ práce studenta

Jméno a příjmení:	**Bc. Daniel SCHNURPFEIL**
Osobní číslo:	**A22N0074P**
Adresa:	Luženická 677, Domažlice – Týnské Předměstí, 34401 Domažlice 1, Česká republika
Téma práce:	Využití metod počítačového vidění ve videozáznamech pro detekci a klasifikaci návěstidel na českých železnicích
Téma práce anglicky:	Computer Vision Applications in Video Recordings for Traffic Signal Detection and Classification on Czech Railways
Jazyk práce:	Angličtina
Vedoucí práce:	Ing. Pavel Mautner, Ph.D. Katedra informatiky a výpočetní techniky

Zásady pro vypracování:

- Seznamte se s problematikou návěstidel a návěstních znaků, zejména se zaměřením na jejich vizuální charakteristiky a odlišnosti.
- Prostudujte videa z veřejně dostupných zdrojů (např. YouTube kanál parnici.cz) obsahující železniční návěstidla.
- Navrhněte a implementujte metody pro získání snímků popřípadě sérií snímků návěstidel/návěstních znaků z dostupných videozáznamů.
- Navrhněte metody a implementujte řešení pro detekci a klasifikaci světelných návěstidel, případně návěstních znaků.
- Na dostatečně velké množině dat ověřte funkčnost implementovaných řešení.
- Zhodnoťte a popište dosažené výsledky.

Seznam doporučené literatury:

Dodá vedoucí diplomové práce.

Podpis studenta: Datum:

Podpis vedoucího práce: Datum:

Declaration

I hereby declare that this Master's Thesis is completely my own work and that I used only the cited sources, literature, and other resources. This thesis has not been used to obtain another or the same academic degree.

I acknowledge that my thesis is subject to the rights and obligations arising from Act No. 121/2000 Coll., the Copyright Act as amended, in particular the fact that the University of West Bohemia has the right to conclude a licence agreement for the use of this thesis as a school work pursuant to Section 60(1) of the Copyright Act.

V Plzni, on 28 February 2025

. . . . . .

Daniel Schnurpfeil

Abstract

English abstract

Abstrakt

Czech abstract

Keywords

computer vision • czech railways

Contents

Introduction

Background on Railway Signaling Systems

Thesis objectives and scope

Czech Railways

todo - tady krátké intro

todo - zmínit evropský zabezpečovací systém, siemens mobility ...

2.1 Situation in Recent Years

todo - tady popsat situaci v čechách a na moravě (slezku)

todo - zmínit - Dopravní a návěstní předpis pro tratě nevybavené evropským vlakovým zabezpečovačem a že to je hlavní zaměření

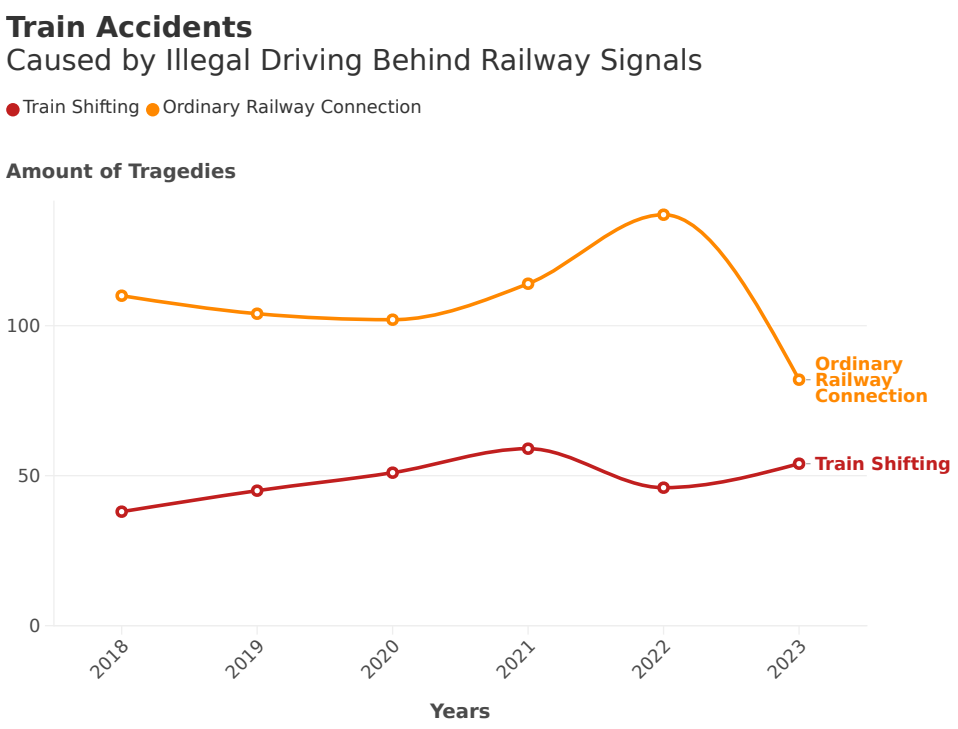

Figure 2.1: Train Accidents Caused by Illegal Driving Behind Railway Signals

2.2 Railway Signals

Railway signals represent a visual communication tool for train drivers. Their main purpose is to show important safety information for train driver. These signals contain specific combinations of lights, shapes, and colors to transmit clear instructions about speed limits, track availability, and required actions.

Light signals on Czech railways operate through a system of colored lights mounted on standardized signal posts. The most frequent signal colors are red, green, yellow, and white, with each color that carry distinct meaning. Red lights typically indicate stop request, while green lights could allow unlimited movement. The yellow light serves as a warning sign, preparing drivers for the following limitations. White lights are often in shunting[1] signals or as additional indicators.

The signals combine these colors in various patterns to communicate more complex messages. For example, two vertically positioned yellow lights (Figure 2.2) inform the driver to reduce speed and expect a stop signal ahead. The position and blinking of light(s) adds another piece of information to the basic colors.

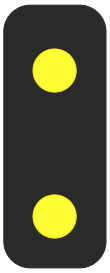

Figure 2.2: Limit 40 km/h and warning

Fixed railway signs complement the light-based system. These include physical signs and markers that display speed limits, distance warnings, and track identification. Their design emphasizes visibility in various weather conditions through reflective materials and high-contrast color schemes. Signal boards often use standardized shapes such as circles or white triangles that serve as warning signs. They are not part of the thesis.

[1] Shunting in railways is the process of moving trains, wagons within a station to assemble, disassemble, or relocate them for operational purposes.

2.2.1 Single-Light Signals

In this section we will, describe single-light signals and their characteristics.

The "Výstraha" signal allows the train to proceed but warns the driver to expect a "Stop" signal at the next main signal, which is placed at least the braking distance away. This signal is essential for preparing the driver for an upcoming stop, ensuring that the train can be safely halted if necessary.

The "Volno" signal indicates that the train can proceed without any speed restrictions. This signal is used on dependent main signals and pre-signals the next main signal, which will also display a permissive single-light signal. The "Volno" signal is crucial for maintaining smooth and efficient train operations, as it allows trains to continue at their maximum permitted speed.

Speed expectation signals, such as "Očekávejte rychlost 40 km/h," "Očekávejte rychlost 60 km/h," "Očekávejte rychlost 80 km/h," "Očekávejte rychlost 100 km/h," and "Očekávejte rychlost 120 km/h," inform the driver of the expected speed at the next main signal. These signals are placed at least the braking distance away from the next signal, ensuring that the driver has enough time to adjust the train's speed accordingly. The specific speed indicated by these signals can vary, with some signals indicating a range of possible speeds.

In cases where a rapidly flashing green light is accompanied by a yellow number, the number indicates the tens digit of the speed limit at the next main signal. This additional information helps the driver to anticipate the required speed adjustments, further enhancing the safety and efficiency of train operations.

Single-light signals play a vital role in the railway signaling system, providing clear and timely information to train drivers. Their design and placement are carefully considered to ensure that drivers can quickly and accurately respond to the signals, maintaining the safety and efficiency of railway operations.

2.2.2 Stop Signal (návěst Stůj)

todo - tady popsat, info ze zdroje - ./czech-railway-trafic-lights-detection/resources/
text_resources/Výtah světelných návěstidel červená.pdf

2.2.3 Multiple-Light Signals

todo - tady popsat, info ze zdroje - ./czech-railway-trafic-lights-detection/resources/
text_resources/Výtah světelných návěstidel ostatni.pdf

2.2.4 Foresignals (Předvěsti)

todo - tady popsat, info ze zdroje - ./czech-railway-trafic-lights-detection/resources/
text_resources/Výtah světelných návěstidel predvesti.pdf

State of The Art

this is related[**Staino2022**]

Data Analysis & Methodology

4.1 Data Resources

4.2 ETL

Study of publicly available sources (e.g., YouTube channel parnici.cz) Methods for extracting individual frames and image sequences ... [**lin2015microsoft**]

4.2.1 Data Annotation

4.2.1.1 YOLO

`Limitations`

4.2.1.2 Heuristics

4.2.1.3 Data Transformation

4.2.1.4 Datat Load

4.3 ROI Detection

Proposed methods for identifying light signals in images

4.4 ROI Classification

- enlarge bounding box (ROI) from yolo detections

Figure 4.1: Original detection example (figure is from [**sprava_zeleznic_predpis**])

Techniques for recognizing specific signal aspects

4.4.1 CNN Architecture Introduction

4.4.2 Yolo

Implementation

Details of the implemented solution

5.1 Dataset Storage

5.2 Experiment Playground

5.3 Training Scripts

Technologies and libraries used

5.4 Applied Technologies

5.4.1 Ultralytics Yolo

5.4.2 Open CV

Challenges encountered and solutions applied

5.4.3 Czech Metacenter

Results

Description of the testing process

6.1 Train Dataset

6.2 Eval Dataset

6.3 Test Dataset

parnici cz a strojvedouci .com

- Process of compiling a comprehensive dataset for testing
- Presentation of results
- Analysis of system performance

6.4 Signal Detection

6.4.0.1 Baseline

6.5 Signal Classification

6.5.0.1 Baseline

6.6 Signal Recognition

Signal Detection

+

Signal Classification

6.6.0.1 Baseline

Discussion

Interpretation of results Comparison with existing methods Limitations of the current approach

Conclusion

Summary of achievements Contributions to the field Suggestions for future work

List of Figures

List of Tables

List of Listings