THE SYSTEM FOR AUTOMATIC TRAIN CONTROL SIMULATION

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Abstract: The paper deals with the issue of the design and implementation of a train control simulator. This system allows evoking different potential traffic situations. It is also possible to search for the best solution of those situations. Much attention is devoted to the image processing possibility. Acquired information from an image can be used for development of a decision support system for rail vehicles. It can be also used for a cargo or an undercarriage inspection of a rail vehicle. The visual information transmission from a rail vehicle into a computer is described in detail. Several methods for image processing have been tested. The best results have been acquired with the Rapid object detection using a boosted cascade of simple feature algorithm. Further in the paper, possibilities of robustness increase as well as time requirements decrease of the whole solution are discussed.

Keywords: decision support system, rail vehicles, image processing.

1 Introduction

Much effort has been devoted to increase the safety of transportation. Intelligent elements are integrated into decision support systems for vehicles, driven by men. This article is focused on land transportation, especially rail vehicles. Systems for scene recognition, traffic signs recognition or rail signs recognition are used as a drive assistant. Advance decision support systems are based on different kinds of sensors. The most sophisticated systems use a computer vision. Some of these systems actively interfere into driving of a vehicle. An example of that functionality could be break activation, when sensors detect an obstacle on the road. Another example could be that those systems can monitor the speed of the vehicle and control it according to a speed limit. In the field of rail vehicles it is not research of decision support systems on that high level. In the Czech Republic, long-term monopole existed in the field of rail transportation in the form of the only one company. The development of decision support systems for rail vehicles was on the brink of interest in the past, due to its influence. Nowadays, competitive environment opens new opportunities for the application of the newest research results.

Two directions of this possible application can be distinguished. One of them is inspection. It can be focused on rails, undercarriage of a vehicle and some cargo. The purpose of this application is to prevent an accident. Image processing algorithms are able to detect parts of rails [8], [4] and vehicles [5], which are damaged. Rail track inspection is time consuming process. Use of computer vision algorithm brings cost reduction and a safety increase. Results from [8] can be seen in Figure 1. Algorithm is able to detect railroad ties (red) and their boundary (yellow), spikes (blue) and anchors of a railroad (green).

Figure 1: Diagram of the whole solution
Source: [8]

A plate on the railroad ties detection is shown in Figure 2. It is detailed look on the rails. Red line shows the rail track detection. Green rectangle identifies the railroad tie. And finally purple rectangle illustrates position of the tie plate. Spikes and anchors detection is realized in the further processing of this image. Then, the system is able to inspect those parts.

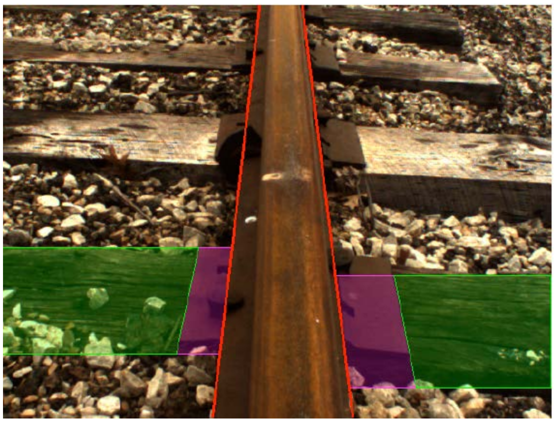

Figure 2: Delineated Tie and Tie Plate location Estimations
Source: [8]

The other direction is rail tracks recognition. This approach benefits from the geometric rules of rail tracks. Another advantage is their continuity. It can be predicted the appearance of the rail tracks in the image sequence. Based on these facts, it is possible to minimize detection error rate. Most often the application of this approach is obstacle detection [3], [2]. First, it is necessary to transform the scene according to geometric rules. Scheme of this transformation can be seen on figure 3. Transform of the Image of the real rail tracks is shown in Figure 4.

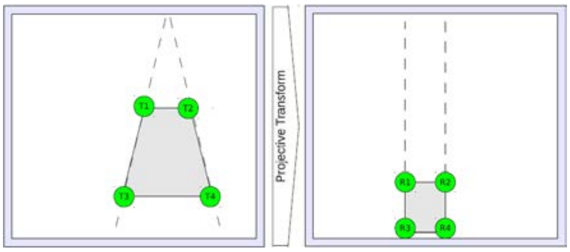

Figure 3: Projective transform mapping the corners of the trapezoid of the cabin view to the corners of the rectangle of the bird's-eye view.
Source: [3]

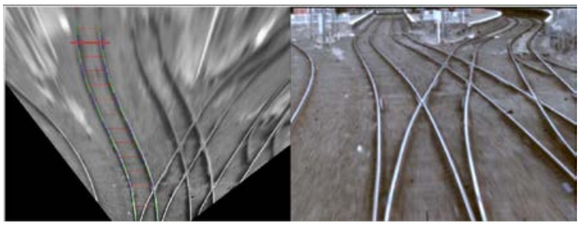

Figure 4: Transform of the image with rail tracks.
Source: [3]

Thanks to this transformation it is possible to detect the rail tracks and also detect obstacles that can be on them. Example of the detected rail track is shown in Figure 5. Red line indicates direction of the track.

The main goal of this work is the design and implementation a train control simulator. It is expensive or nearly impossible to create some traffic situations in real environment. This simulator allows to explore these situations. That was the motivation for creating this solution. This system serves mainly for supporting a research activity. Supporting of an educational process is the secondary goal.

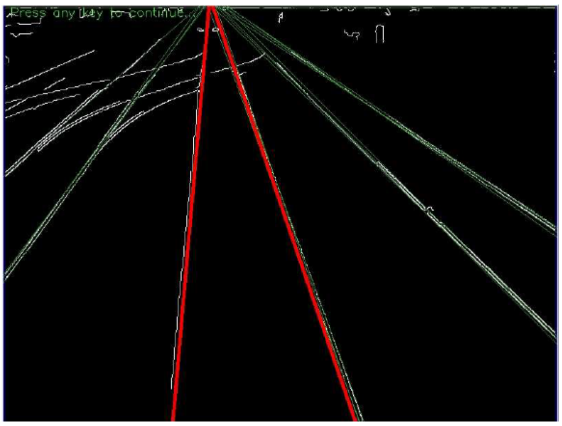

Figure 5: Detection of rail tracks.
Source: [3]

2 Used approach

The system for simulation of the train control was created in the laboratory of the rail vehicles that exists at Mendel University in Brno. A model railroad with different kinds of rail vehicles is available in the laboratory. Scales of the models are H0 (1:87) and TT (1:120). Vehicles can be controlled from a computer. Software can work automatically or in a manual regime. Vehicles are controlled by signals, which are modulated and distributed through the rail tracks together with the power supply. These vehicles are equipped with microcontrollers, which allow controlling two user outputs. User can control electronic in the vehicle using these outputs. Power supply for the whole vehicle is realized by the collector placed on the wheels.

The paper is focused on image processing. The main goal is to acquire information suitable for controlling a rail vehicle. Integration of miniature cameras into rail vehicles was necessary for a proper function of the whole system. Camera connection to the computer is wireless. A/D converter serves for digitization of the visual information. Images are processed in C++ programming language using OpenCV library (Open source computer vision) [6]. Two methods for object recognition were tested. Speed up robust features [1] and rapid object detection using a boosted cascade of simple feature [9]. The scheme of the whole designed solution is shown in Figure 6.

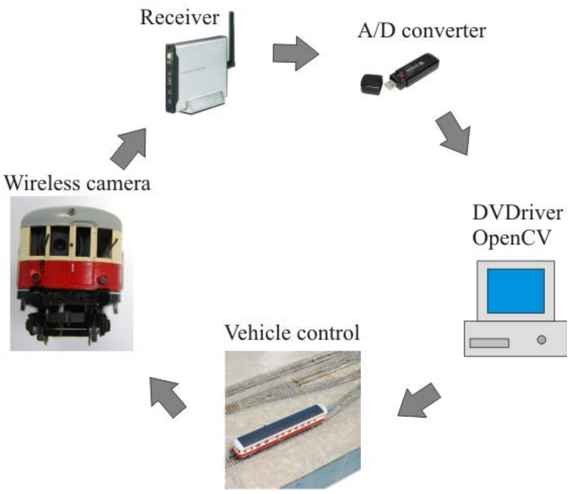

Figure 6: Diagram of the whole solution

Computation load is increasing according to the number of searched objects. The problem of higher time consumption of the Rapid object detection using a boosted cascade of simple features algorithm can be partially avoided using the dedicated powerful server. Image, acquired by the camera is send via computer network for further processing. This approach can bring significant time saving. The solution to this technical problem is discussed in detail in [7].

3 Achievements

Integration of a small camera into a model of a rail vehicle was the first step. A set of a wireless camera with a receiver was used. The camera is supplied direct from the rail tracks in the same way like the model vehicles. Supply voltage for the camera is adjusted by a DC to DC converter, see Figure 7-B2. The front and side views of an integrated camera is shown in Figure 7-A and 7-B1. The camera is controlled by the microcontroller of the vehicle, see Figure 7-B3. It is possible to focus on objects in a specific distance thanks to manual focus of the camera. This approach allows to take a sharp image of the object (e.g. traffic sign).

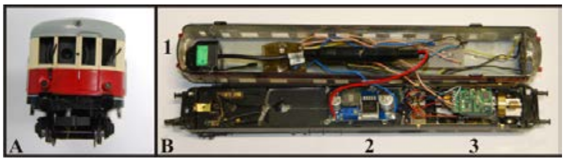

Figure 7: Integrated camera: A) front view, B1) side view, B2) DC/DC converter, B3) microcontroller

The camera is sending an analogues signal according to the PAL standard with resolution 720×576 px. The transfer of an image is realized in 2.4 GHz. The analogue signal is the output of the receiver. A USB A/D converter is used for the received signal digitization. A video stream is necessary for further processing. The converter itself cannot create a stream. DVDriver software is used for creation of a video stream. This software is able to emulate a webcam, so it is possible to grab an image in any time moment.

The OpenCV library [6] is used for image processing. C++ is used as the programming language. The input image is acquired from the DVDriver software in the real time. Two states of the art algorithms were used for the purpose of traffic sign recognition. One of them was Speeded up robust features [1]. The algorithm searches important points in an image. These points represent a specific object. Unfortunately, this algorithm application does not bring desired results. The biggest problem was high false positive rate. Better results were achieved with Rapid object detection using a boosted cascade of simple features algorithm [9]. Images obtained from the camera were used for training of a classifier. The algorithm needs positive and negative images for training. Positive samples were processed using createsapmles utility from OpenCV. From one traffic sign in an image it is possible to create more positives samples. The sample position is deformed and simulates the view under different angles. This approach is possible, because a traffic sign is a 2D object. Another source of positive samples could be the document from Railways of the Czech Republic company: „Dopravní a návěstní předpis". Generated positive samples are then stored to the vec file. Images obtained from the record of the rail tracks serve as negative samples. The negative samples do not contain desired traffic signs. Hundreds of the negative samples were used for training. After training, the classifier was able to detect the desired traffic sign, see 8-A. False alarm rate was acceptable during testing rides. The system proved the ability to detect the sign even in a noisy image, see 8-B.

Information obtained from the surrounding environment makes possible the adaptive control of the rail vehicle. The speed and direction of the vehicle can be changed based on this information.

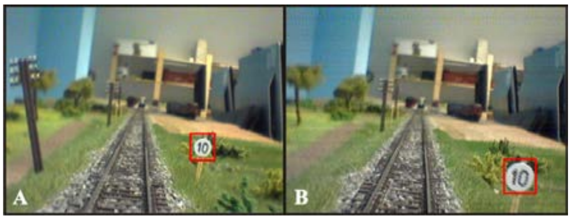

Figure 8: Sign detection: A) good quality image, B) image with noise

4 Discussion

The described system is able to recognize rail traffic signs in a given environment. A little disadvantage could be a relatively complex process of classifier training. Especially preparing the samples is demanding. Training of a classifier is also a time consuming process. But, it is necessary to do these steps only once for each object. The detection process input is a cascade of simple features.

The acquired video stream is delayed about one second in comparison to the real time. It depends on wireless signal quality. The delay is caused by the wireless connection of the camera and need of the digitization process. That is a disadvantage from a technical view. This delay is not a critical obstacle for the research in the laboratory. In reality this delay can be eliminated using an industrial camera with a USB3 connection.

4 Conclusions and future work

In the paper there is described the system for automatic train control simulation. It is focused on the computer vision. Its technical solution of image transmission from a rail vehicle into a computer is described in details. Two methods for scene recognition were tested. The first method, Speed up robust features, does not bring desired results. Problem being, the too high false positive rate. The second method, the Rapid object detection using a boosted cascade of simple features provides sufficient results. Thanks to this, it is possible to continue in the research in the field of automatic train control.

The future work will be focused on increasing robustness of the proposed system. The approach in image processing and the scene recognition can be improved. The rail traffic signs and railroad have clear geometric rules. Thanks to those rules, it is possible to reduce a size of a search area in an image. The smaller search area can bring a significant reduction of a computation load and increase of reliability of the system.

The proposed system allows evoking different potential traffic situations. Also it is possible to search for the best solution of those situations. Simulations can be focused on testing of Decision support systems, rail vehicles inspection and obstacle detection on the rail tracks.

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