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Research Paper

Detection of Foreign Objects Around the Railway Line with YOLOv8

Mehmet Sevi*[1], İlhan Aydın[2]

[1] IT Department, Muş Alparslan University, Muş, Turkey

[2] Department of Computer Engineering, Fırat University, Elâzığ, Turkey

(m.sevi@alparslan.edu.tr, iaydin@firat.edu.tr)

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Abstract— This study proposes a deep learning-based method to detect foreign objects around the railway line. It is important to make this determination with high accuracy for rail transport safety, but traditional methods are disadvantageous in terms of time and cost. In the proposed method, the RailSem19 dataset was used, and a YOLOv8-based model was designed. YOLOv8 is a prominent algorithm in the literature with its fast and accurate object detection capability. In the study, the dataset was diversified using image enhancement techniques. The training, validation, and testing stages used manually labeled data for human and car classes. The training process was carried out through Google Colab and different YOLOv8 sub-architectures were evaluated. The results showed that the YOLOv8m sub-architecture had higher mAP50 values than the other sub-architectures and showed a successful performance in the validation phase. The YOLOv8m model was able to clearly distinguish people and cars around the railway line. The YOLOv8m sub-architecture achieved a mAP50 value of 88.8%. This study presents an automated and efficient method to improve rail transport safety. The high success of the YOLOv8-based model with the RailSem19 dataset can be considered an effective solution to detect potential risks around the railway line.

Keywords : *Object Detection, YOLOv8, Deep Learning, Railway*.

1. Introduction

Railway transportation, which has been used for many years throughout the world, started in 1856 with the establishment of a 130 km railway network between İzmir and Aydın in our country (Çağlıyan, 2013). With the development of high-speed trains, railway transportation has become a fast and comfortable mode of transportation that is widely preferred by people in our country in recent years. Railway cars need railway lines to provide this transportation. However, the fact that cars such as trains with large masses move on this line makes the maintenance and safety of the line extremely important.

The rapid growth of railway networks and their great potential have made railway transportation very attractive. For this reason, in recent years, railway transportation has become one of the intensively studied subjects. (Güçlü, 2021). The railway is all of the facilities that enable the transportation of people and goods in metal-wheeled cars that are moved from one place to another on a metal road by mechanical power (Aydemir, 2016). The development of high-speed trains has also increased the annual number of train passengers. In traditional methods, objects around the railway line are still tried to be detected by human examination. However, these methods cause low sensitivity and accuracy rates in foreign object detection.

There are many studies in the literature on the detection and real-time monitoring of the railway track and its components. However, foreign objects are ignored in studies in the current literature. In particular, it negatively affects the detection and monitoring of railway components. As a result of the research carried out in the study, it was observed that there were garbage and other foreign objects along the rail line. Foreign objects are very common, especially on railway lines close to settlements. These objects not only make the track and its components difficult to detect but also pose a threat to railway transportation security. Foreign objects (iron, steel materials, rocks, tree branches, etc.) on the track may cause the train to derail. Solving this problem and detecting foreign objects around the railway line constitute the main motivation of the study.

In a study in the literature (Hyde, 2022), they proposed a model for obstacle detection and intrusion and examined different levels of automation for the automatic operation of railways. Tastimur et al. an image processing-based method has been proposed to prevent accidents at level crossings. The distance between the detected foreign object and the camera was calculated in the method they proposed (Tastimur, 2017). Another study in the literature (Han, 2018) developed a computer vision algorithm to automatically detect defects in insulators in the catenary system. The algorithm they developed consists of two stages. In the first step, they identify the insulators. In the second stage, they detect the defects in the insulators. A local density period estimation algorithm was designed to detect defects in insulators. In the experiments, they reported that the algorithm they developed detected the breakage of ceramic discs and foreign objects stuck between two discs. In a study in the literature on railways (Cao, 2022) they proposed a method they called "RailDet" to detect intrusions in complex railway images. In the two-stage method, firstly, the rail zones and intruder objects to be accepted are determined. When the object enters the forbidden zone, the deep learning-based object detection algorithm in the second stage of the method works. The proposed method works on camera images fixed at certain points around the railway. Cao et al. state that this system can also be used at fixed camera observation points in sectors other than railways. Another study in the literature on railways (Chen, 2022) proposed a semi-supervised method to detect defects on non-ballast surfaces. They assumed that there was no foreign object between the rail and the fastener and used the Mask R-CNN algorithm to remove these regions.

In this study, foreign objects around the railway line were detected by deep learning methods. It is important that this process is done with high accuracy for the safety of railway transportation. Traditional methods are disadvantageous in terms of time and cost. Therefore, automatic analysis of these data is more efficient for rail transport safety. In this study, a YOLOv8-based method that detects foreign objects around the railway line using railway images from the Railsem19 dataset is proposed. In the second part of the article, the proposed method, dataset, and preprocessing steps are explained. In the third part, the experimental results are presented. In the last section, the results of the proposed method are discussed.

2. Method

In the study, a method has been proposed in order to detect foreign objects around the railway line. YOLOv8, which allows object detection, was used in the method developed for detecting two foreign objects in total, including people and cars, around the line. RailSem19 (Zendel, 2019) dataset was used in this study. A dataset including foreign objects is needed to ensure the driving safety of railway cars. A common reason for this is that the content of datasets available to researchers consists only of railway images. RailSem19 was put into the service of researchers by the Austrian Institute of Technology staff in 2019 in order to eliminate this deficiency in railway transportation studies. The RailSem19 dataset consists of 8500 original high-resolution images of a railway car taken from the machinist's perspective. Examples of images in the dataset are given in Figure 1.

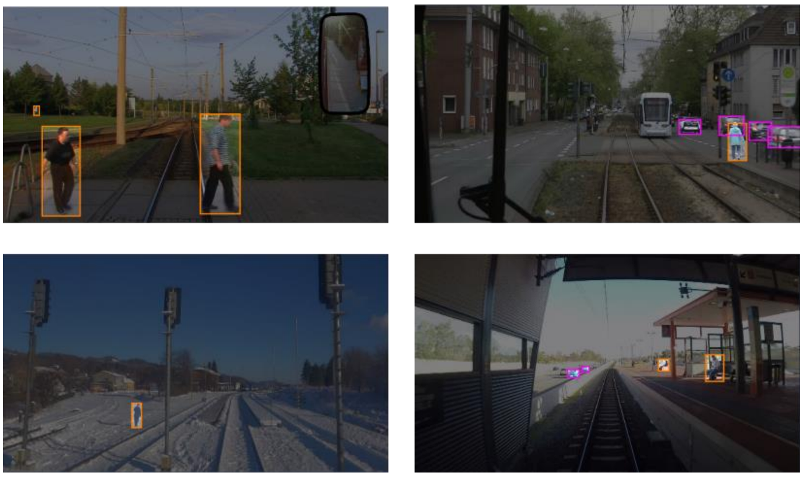

Figure 1. Examples from the dataset

There are 19 classes in the RailSem19 dataset. In this study, human and car classes were manually labeled and made ready for use in training, validation and testing stages. Several data augmentation methods such as image flip, noise addition and brightness adjustment were used in the study. Image flipping is the process of obtaining a new image by rotating an image along the x-axis or y-axis. (Sevi, 2023) Noise addition is the process of increasing the noise level of an image by randomly adding additional information on each pixel of an image (Sevi, 2023). Brightness variation is a direct linear transformation operation on each pixel of an image. Using λ as the image brightness conversion factor, the image sample expanded by brightness variation can be expressed as I=λI. Here 0< λ<1 represents darkening and λ>1 represents brightening. (Sevi, 2023).

With the YOLOv8-based model, objects that may pose a potential risk around the railway line will be detected. YOLO (Just Look Once) is a deep convolutional neural network inspired by GoogLeNet. It detects objects by traversing the image through a single neural network and estimating bounding boxes and class probabilities. This makes it the fastest general-purpose object detection architecture in the literature. It is also the first reported real-time convolutional neural network-based object detection model. Since the entire sensing line is in a single network, the direct sensing performance is higher than most other neural network architectures (Ju, 2023).

YOLOv8 is an object detection algorithm created by Darknet in 2021. It is an update of the YOLOv4 algorithm and is faster, more accurate, and requires fewer resources. Our YOLOv8 model architecture consists of a backbone, neck, and head as shown in Figure 2 (Kılıç, 2022). YOLOv8 is a powerful algorithm for object detection. It is faster, more accurate, and requires fewer resources, making it a suitable choice for real-time object detection and object detection on lower-power devices. The sub-architectures of YOLOv8, YOLOv8n, YOLOv8s, YOLOv8m, YOLOv8l and YOLOv8x, were used in the study. In the study, it was observed that YOLOv8 was very successful in evaluating the mAP50 performance metric compared to its competitors in terms of time and accuracy parameters (Ristić-Durrant, 2020).

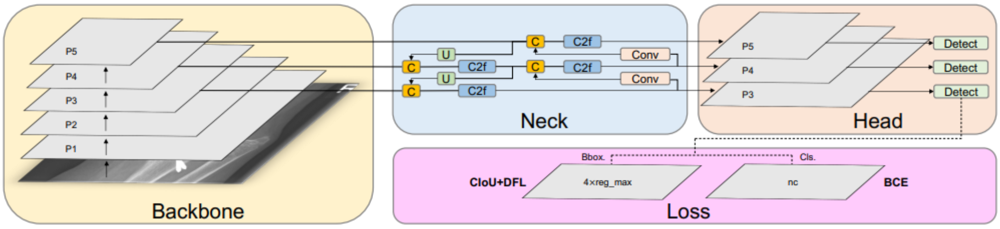

Figure 2. YOLOv8 architecture

3. Experimental Results

The training phase was done with the Google Colab tool in all models. The experimental environment consists of Tesla P100- PCIE-16GB graphics processor unit (GPU) and Intel(R) Xeon(R) central processing unit (CPU) @ 2.20GHz CPU system. As the data size, 640x640 resolution is set to 25 as the preferred number of cycles. SGD as an optimizer, learning rate set to 0.01. The training results are shown in Table 1.

Table 1. Training results

Sub-Architecture	mAP50	mAP50 (Car)	mAP50 (Person)	Training Time (Hour)
YOLOv8n	0.837	0.890	0.784	0.248
YOLOv8s	0.848	0.908	0.788	0.251
YOLOv8m	0.888	0.939	0.837	0.341
YOLOv8l	0.859	0.922	0.797	0.441
YOLOv8x	0.862	0.919	0.805	0.671

According to the training results in Table 1, YOLOv8m was more successful than other YOLOv8 sub-architectures in average and class-based mAP50 values. YOLOv8m was slower in terms of training time than YOLOv8n and YOLOv8s sub-architectures. But it achieved better results in terms of success rate. Table 2 shows the results of the straightening.

Table 2. Validation results

Sub-Architecture	mAP50	mAP50 (Car)	mAP50 (Person)
YOLOv8n	0.843	0.895	0.791
YOLOv8s	0.865	0.919	0.811
YOLOv8m	0.888	0.943	0.833
YOLOv8l	0.859	0.921	0.797
YOLOv8x	0.871	0.915	0.827

Looking at the validation in Table 2, as in the training phase, the YOLOv8m sub-architecture was more successful in average and class-based mAP50 values compared to other sub-architectures. The test results of the YOLOv8m sub-architecture are shown in Figure 3. As seen in Figure 3, objects such as people and cars are clearly distinguished in the images.

Figure 3. Test results of the YOLOv8m sub-architecture

4. Conclusion

In this study, an automatic, deep learning-based system is proposed for the detection of foreign objects around the railway line. With the proposed system, the YOLOv8 model has been proposed to detect foreign objects around the railway line in a contactless and non-occupying way. In studies in the literature, YOLOv3 and YOLOv5 object detection models were generally used together with the RailSem19 dataset (Jahan, 2021; Klammsteiner, 2023; Evain, 2023; Chen, 2022). The RailSem19 dataset contains images of the railway line located in both rural and urban areas. Transportation cars such as trams used in the city have the potential to cause more accidents with people and other cars. In the study, images of both rural and urban lines were used in the training, validation, and testing stages. A deep learning-based approach has been proposed to automatically perform analyses from the augmented data. The YOLOv8 sub-architecture of the YOLOv8 model has achieved a mAP50 value of 88.8% on the augmented dataset.

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