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# Vision-Based Rail Inspection Systems

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***Abstract:-*** **Computer vision-based condition monitoring methods, the methods are increasingly used on railway systems. The rail condition monitoring process can be performed using data obtained with the help of computers using these methods. In this study, a computer-based visual rail condition monitoring is proposed. By means of a camera placed on top of the train the rail that the train is on and the neighbour rail images are taken. On these images, the edge and feature extraction methods are applied to determine the rails. The resulting several faults between railways were studied to determine if there is a failure. The results obtained are given at the end of the study. Experimental results show that the proposed method is examined, it is observed that a healthy and effective results.**

***Index Terms*** **— Condition monitoring, railway systems, image processing, fault diagnosis.**

## I. INTRODUCTION

Rail transport, in particular, a type of transport used for many years because of cost and safety advantages. Security and maintenance of railroads use increased with the development of technology in this field is important at the same rate. In particular, it can continue to use in a healthy manner and in condition monitoring of rail tracks directly affects the safety of the track. Traditionally these processes are generally provided in a manner based on human power. However, these methods are having some disadvantages in terms of both cost and get good results [1]. In recent years, advances in technology have led to development of methods based on the power in this area. With falling costs of computer and electronic hardware and developing software techniques provide effective results of the work in this area. There are many studies in the field of monitoring of computer-based vision of railways [2]-[4]. In one of these studies, Khan et al., have proposed a machine vision method to determine the anchor and ties [5]. In this study, E-type anchors are tried to be determined. Feature extraction methods are used in the presence of fault. The test results and the success rate obtained by the method are given in the results section. A block diagram of this study are given in Fig. 1. Singh et al., a control method is proposed to detect faults of tie plates [6]. One light source is placed under the train and one camera. After obtaining the clips using the edge extraction algorithm, hue of the clips are determined. According to hue, it is determined that the clip is old or robust or broken. The results obtained from this study are presented in tables with accuracy rates. Proposed in another study, Trinh et al., aims to determine the damage to the elements on the rails [7]. In the method, four camera and distance measuring device is used. The purpose of the method; determination of the screws is to identify the damaged structure and pattern of inappropriate components. In another study, Trinh et al., are working to identify compliance problems and rail connections [8]. Sobel edge extraction method is used on images taken with the aid of a camera. For object extraction processing, Hough transform method is used. The obtained data, a comparison process is carried out to determine the compliance issues. Thus the incompatibility of the anchor and faults are determined. In conclusion, the results obtained are given.

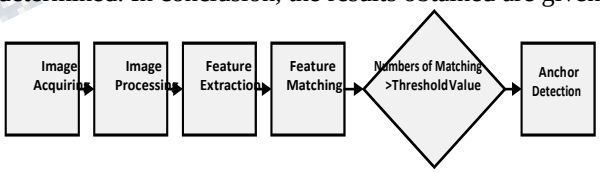



***Figure 1. Block diagram of the method that anchor determined [5].***

In another study Bin et al., are proposed a computer vision based method to determine faults and curves [9]. There are two main units in the proposed method. Image Acquisition Subsystem (IAS) and Image Processing Subsystem. IAS unit is composed of a LED light cameras and 4. IAS unit is designed to perform three operations; Expansion of rail tracks, improving contrast and makes the detection of the fault process. In a different study Sawadisav, it presented a study for the presence of faults [10]. In this study, the potential error conditions using information received from the Federal Railway accidents have been identified. For object recognition, switching rails, anchors and screws are prepared in the laboratory and the sample pattern information has been prepared. Two different algorithms are

proposed. The first algorithm to determine the connecting component, and the second was performed to determine edge and content. At the end, results are given for different types of faults. In another study Chan et al., propose a method in order to determine damage caused by the load on rails [11].The basic process of the study; image acquisition, feature extraction, error identification and fault detection. Similarity metrics, mathematical methods and pattern recognition processes were carried out using fuzzy logic. The results obtained testing real images. Trinh et al., are proposed a method of integration and optimization with multiple sensors for railway control [12]. In the proposed method, a new global optimization method using a plurality of distance measuring devices for rail object recognition using cameras developed. Defects in parts during inspection, alignments, surface defects and curvature have been identified. Quingyong et al., have tried to identify faults occurring in rail-based image processing surface in real-time to develop a non-contact method [13]. Ray surface were determined by the feature extraction ray images. Surface defects were found with the contrast enhancement method. In a different study, Zheng et al., proposes a method for finding the real-time ray measurement point [14]. Operations were carried out using a CCD camera and the red laser light. In the image processing stage, object recognition, differential, adaptive threshold, morphological operations are used.

Ying et al., proposed a rail detection component for automated monitoring and evaluation approach in rail systems [15]. The proposed method, was operated by a train watching with 16km/h. On the acquired images, Sobel edge extraction algorithm and Hough transformation are applied and rail component detection has done [16], [17].

In this study, a computer vision-based condition monitoring is proposed. In the study, a camera placed on top of the train used for image acquisition. Images are taken with placed on the upper part of the camera, the rail where the train that cruising on and neighboring track. On the acquired images, edge extraction, morphological processing and feature extraction methods are applied. Then, the several faults between the rails results are obtained. Experiments were performed using images taken from the real environment and the results obtained have confirmed the validity of the study.

## II. PROPOSED APPROACH

In this study, a new computer vision based method is proposed for analyzing the rail that one of components of railway systems. There are image processing based several techniques in the literature [16]-[18]. The rails are determined by means of image processing techniques using the proposed method. The distance between the rails is determined again by image processing. Thus, it is determined that there is any problem between the rails. In order to perform these operations on the locomotive it was placed one camera. In the proposed approach, the rail locomotive cruising on and neighboring the rail are analyzed. In these analyzes, the several fault types between the rails is calculated. Thus, significant problems can be avoided that might occur in the future. A block diagram illustrating the operation principle of the proposed approach is given in Fig. 2. Also, the detected faults are presented in Fig. 3.Mainly used for a camera system can be seen from Fig. 2. Images from the camera are used to calculate the several faults such as pitch, expansion between the rails. The main objective of the proposed approach by calculating the distance between the rails is to determine whether any problems. Accordingly, it is determined whether any contraction or expansion between the rails.

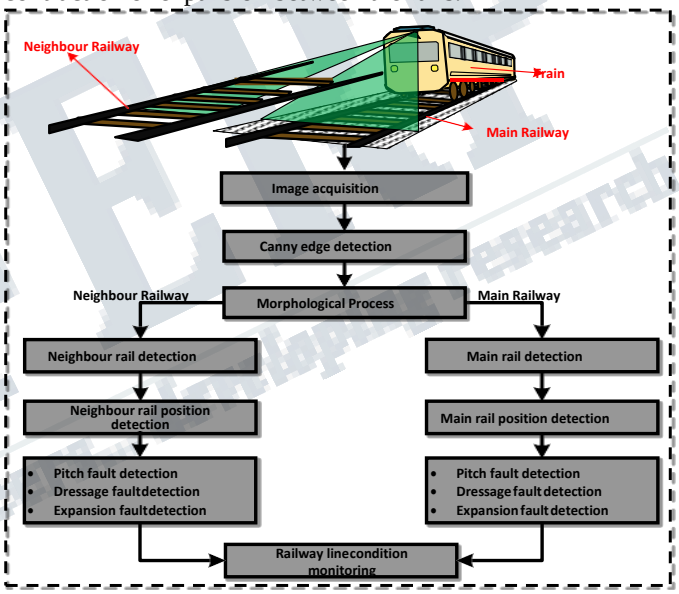
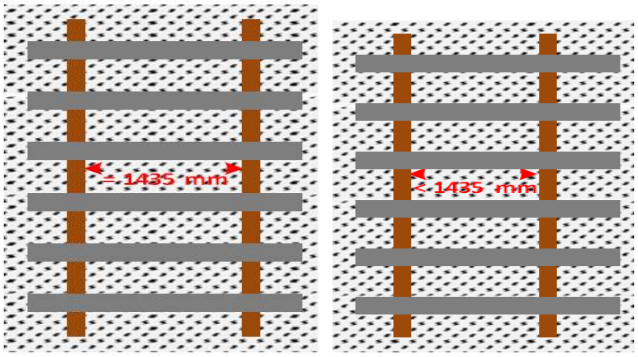



*Figure 2. The proposed approach*




*(a) Normal Condition* *(b) Pitch Fault*

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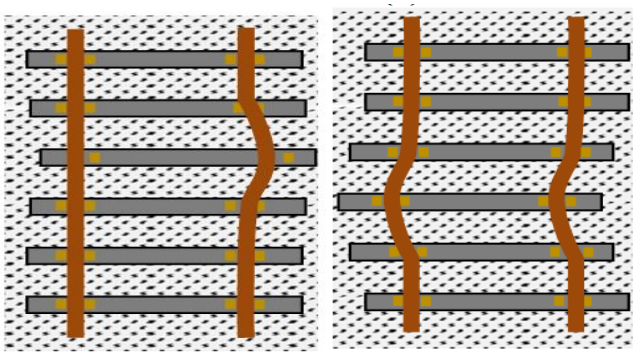


*(c) Expansion Fault (d) Dressage Fault*

***Figure 3. The faults detected on the proposed approach***

In this way, the train rails are provided to take the lead without any trouble. If there is any fault detection, it will be provided at the time of manufacturing solutions to problems. The proposed method distinguishes the most important points of the literature, it can be examined in neighboring rails. In addition, the current rail cruising on, also neighboring rail are examined simultaneously and examining the faults between the rails is determined that there is any problem. Proposed by this approach offers a highly innovative solution both in terms of cost and efficiency. Images from a railway order to test the actual work performed is examined with the proposed approach. These images using the proposed method, the distance between the rail cruising on and neighboring rail was calculated respectively. Between the rails with this approach it is determined whether any expansion or contraction. Image processing algorithm has been carried out on images taken at the study. Rails mainly are determined initially by the image processing algorithm. The distance between the marked tracks is calculated using image processing algorithms. The distance between the rails pixels values are obtained. In the proposed approach, and finally it analyzed the change of the pixel value. According to a user-defined threshold value determined as the sudden changes in the pixel values examined it offers detailed information about whether any contraction or expansion between the rails. If the obtained distance above a determined threshold value, means that the expansion of the rails. Likewise, in case of falling below the threshold value it is determined to be contraction in the rails. Such problems are important conditions that could prevent trains to travel safely, the detection of this fault with the work previously done will prevent major accidents will happen in the future. A flow diagram summarizing proposed image processing algorithm used in the approach and example outputs obtained from the image processing algorithm an image is as shown in Fig. 4 and Fig. 5, respectively.

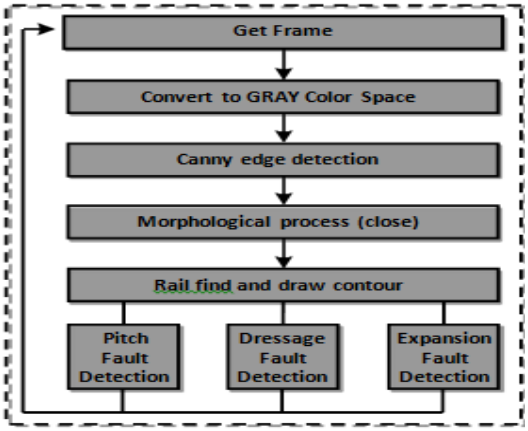
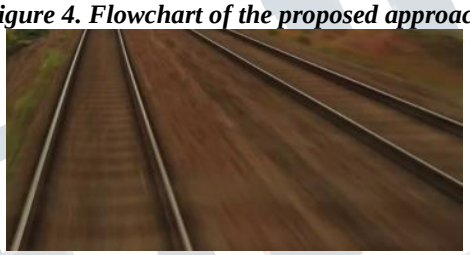
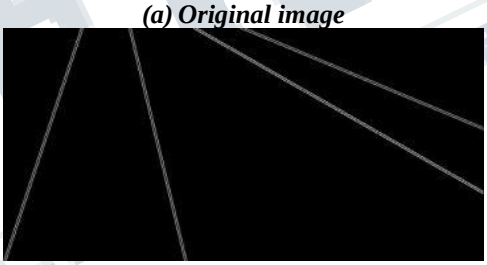



***Figure 4. Flowchart of the proposed approach***

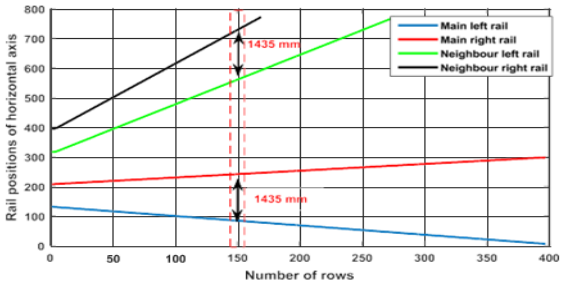


*(a) Original image*



*(b) Canny edge detection*

*(c) Closing process*




*(d) The rails positions in the horizontal axis*

***Figure 5. Image processing steps and example results for sample image frame***

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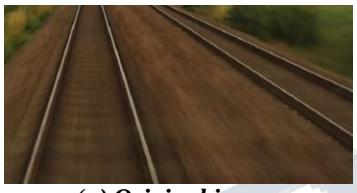
The first image from the camera is taken as the proposed approach can be seen in Fig. 4. Get this image in RGB format is converted to the Gray color space. Following this process, the image on the Canny edge extraction algorithm is applied. After edge detection process, various morphological operations such as closing is applied. In this way the rail sections in the image are obtained exactly. In this image, the rail sections as white color, and the remaining objects are represented in black color. The purpose of this process is to measure the distance between the rails more comfortable. Finally, the distance between the rail profiles marked as white binary image pixels and pixel values are determined in each image frame to be examined according to user-defined thresholds are recorded. After the image processing of these steps is completed, the pixel values are rendered graphically representing the distance between the rails and the observation of changes in these values between the rails is determined whether any contraction or expansion.

***TABLE I. CAMERA AND EXPERIMENTAL FEATURES***

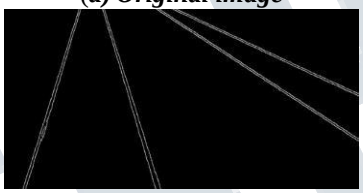
| Camera Features | | Experimental Features | |
|---|---|---|---|
| **Feature** | **Value** | **Feature** | **Value** |
| Resolution | 1280x720 px | Image Refresh Rate | 10 image/sec |
| Frame Rate | 100 fps | | |
| Shutter Type | Global | Time of Day | 01:00 p.m./2:00 p.m. |
| Mono/Color | Color | Cloudiness of Day | Sunny |

## III. EXPERIMENTAL RESULT

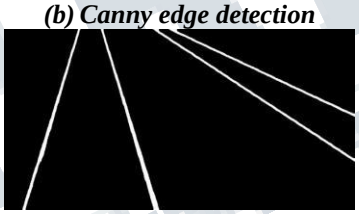
In order to test the proposed approach one camera was placed on a real locomotive. In the images from this camera is recorded and analyzed by computer image processing algorithm. Real-time images taken on this camera sees both the rail cruiding on and the neighboring rail. These two rails are fully determined by the image processing algorithm performed. Finally, the distance and several faults between the rails are calculated from the pixels and observed changes in the pixel values. Properties of the camera used in this study are given in Table I. The camera can take 100 image frames per second as can be seen from Table I. However, the studies are not used all of these image frames. The main reason is to make the process faster and less tiring to the processor. Performed were examined 10 image frames per second in experimental studies and all of the specified operations are performed on these images. As stated in the beginning section, the camera is placed on a locomotive. Received images are transferred to a computer. The rails are identified with the help of image processing algorithm. The distance between the rails are calculated in pixels. After that, the pixel values is converted to metric values by making calibration settings. These calculated values were analyzed by the graphical representation. Problematic situations that occur out is removed. Fig. 6 presents the results for the pitch scenarios shown image frames and the values obtained from the image frame.



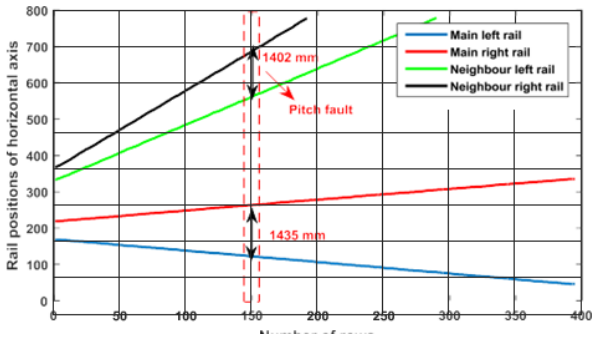
***(a) Original image***



***(b) Canny edge detection***



***(c) Closing process***




***(d) The pitch fault***

***Figure 6. The detection of pitch fault in sample image frame***

As can be seen in Fig. 6-(d), the main rail track is healthy. But, the neighbor rail track have a contraction problem. The distance between two rails is normally 1435 mm. However, this value is calculated as 1402 mm in the neighbor rail. The pitch fault can cause the rail wear and the train derailment.
The expansion fault detection is shown in Fig. 7. The faulty image frame is presented in Fig. 7-(a). The main and neighbor rail track is determined by applying the

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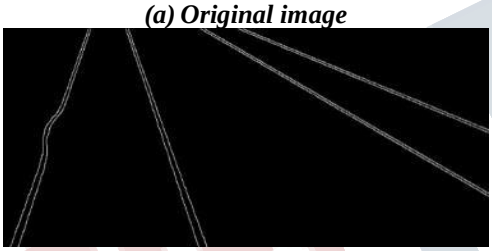
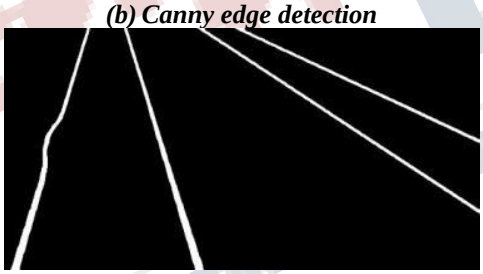
proposed method on this image. The positions on the horizontal axis of detected rail track is calculated. After this process, the expansion fault is detected in main left rail. This situation is given in Fig. 7-(d). The proposed approach is perceived as a fault if there is a sudden change in the position on the horizontal axis of rail track. If one of the rail track is healthy and other is faulty, this situation is expansion fault. There is not any change in main right rail while there is a sudden change in main left rail in Fig. 7-(d). A sudden change is detected in horizontal position of main left and right rail in Fig. 8-(d). Because both right and left rail track fault occurs, this type of fault is dressage. The sample image and the results of dressage fault is presented in Fig. 8

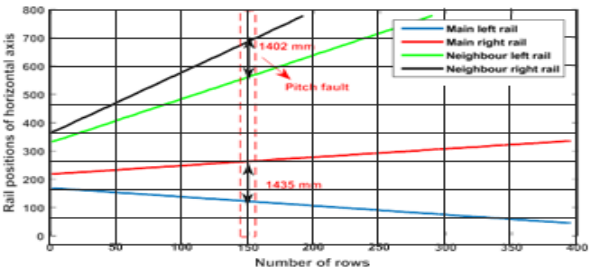
*(a) Original image*



*(b) Canny edge detection*



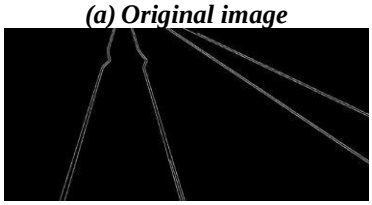
*(c) Closing process*



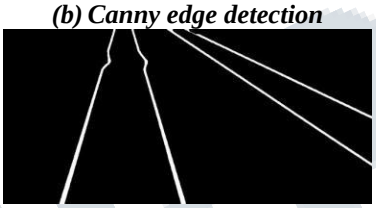

*(d) The expansion fault*

***Figure 7. The detection of expansion fault in sample image frame***

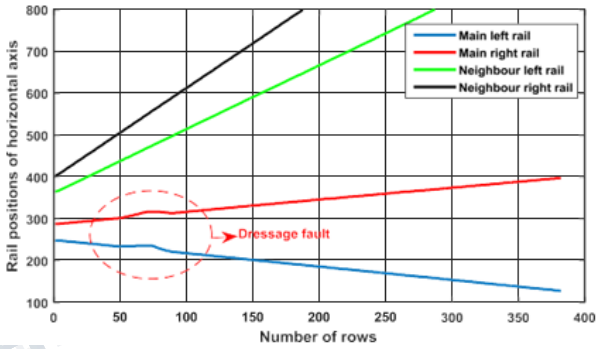
*(a) Original image*



*(b) Canny edge detection*



*(c) Closing process*




*(d) The dressage fault*

***Figure 8. The detection of dressage fault in sample image frame***

## IV. CONCLUSIONS

The use of the railways with the developing technology is continuously increasing. However, some faults occurring on the railways, despite this growth, gives rise to serious accidents. In this study, a computer vision-based methods have been proposed for condition monitoring on the railways. In the proposed approach, images of both the rail cruising on and the neighboring rail are taken with the aid of a camera placed on the locomotive of images. Rail tracks, is determined by applying some image processing algorithms on the images taken. Following this procedure the distance between the rails are calculated from the pixels, and is recorded for inspection. Based approach to examine the change in pixel values between the rails whether any

shrinkage or expansion, is detected accurately and reliably and easily. The most important advantage of the proposed approach, the neighboring rail is also monitored by a single camera. In experimental work carried out using the recommended approach quite efficient results have been obtained.

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