ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# A Novel Railway-Detect Detection System by Using Fastener Classification


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***Abstract***

***The detection of fastener defects is an important task in railway inspection systems, and it is frequently performed to ensure the safety of train traffic. Traditional inspection is usually operated by trained workers who walk along railway lines to search for potential risks. However, the manual inspection is very slow, costly, and dangerous. This paper proposes an automatic visual inspection system for detecting partially worn and completely missing fasteners using probabilistic topic model. Specifically, our method is able to simultaneously model diverse types of fasteners with different orientations and illumination conditions using unlabeled data. To assess the damages, the test fasteners are compared with the trained models and automatically ranked into three levels based on the likelihood probability. The experimental results demonstrate the effectiveness of this method.***

***Index Terms— Fastener, latent Dirichlet allocation (LDA), railway, structure modeling, visual inspection.***

## INTRODUCTION

RAILWAY inspection is a very critical task for ensuring the safety of railway traffic. Traditionally, this task is operated by trained human inspectors who periodically walk along railway lines to search for any damages of railway components. However, the manual inspection is slow, costly, and even dangerous. With the extension of high-speed railway network, the inspection and maintenance face more challenges than ever before. Recently, the railway companies of all over the world are interested in developing automatic inspection systems, which are specialized trains and are able to detect railway defects very efficiently [1].

An automatic railway inspection system is composed of a number of functions such as gauge measurement [2], trackprofile measurement [1], [3], track-surface defects detection [4], and fastener defects detection [5], [6]. The fasteners are used to hold the track on sleepers, as shown in Fig. 1, while the worn and missing fasteners shown in Fig. 2 are hazardous defects, which would cause the displacement of track and even threaten the safety of train operation. Generally speaking, there are two kinds of fasteners: 1) hexagonal-headed bolts and 2) hook-shaped fasteners.

The hook-shaped fasteners are widely used in current railway lines. However, their diverse shapes give rise to significant difficulties in both modeling and inspecting. In this paper, multiple types of hook-shaped fasteners and hexagonal-headed bolts are jointly concerned.

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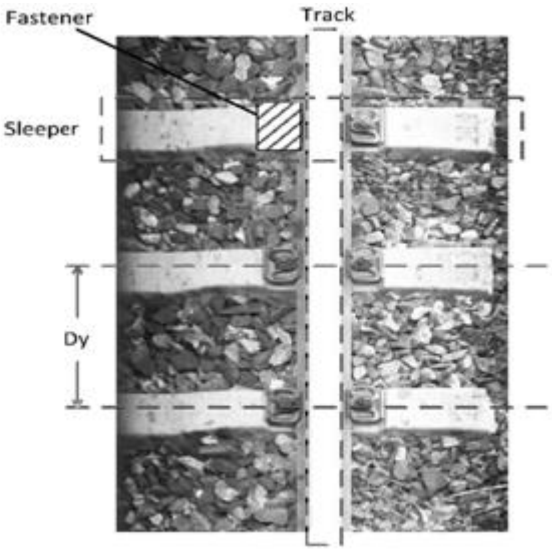

Image captured by onboard camera.

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In the past decade, some researchers have devoted into developing fastener inspection methods. For hexagonal-headed bolts, Marino *et al.* [7] used a multilayer perception neural classifier to detect missing bolts. For hook-shaped fasteners, Stella *et al.* [8] employed wavelet transformation and principal component analysis to preprocess railway images and searched for the missing fasteners using the neural classifier. Similarly, Yang *et al.* [9] took advantage of direction field as the template of fastener. For matching, they use linear discriminate analysis to obtain the weight coefficient matrix. To achieve real-time performance, Ruvo *et al.* [10] applied the error back propagation algorithm to model two types of fastener. They implemented the detection algorithm on graphical processing units. Ruvo et al. [11] also introduced a FPGA-based architecture for automatic hexagonal bolts detection using the same algorithm.

However, the methods mentioned above cannot identify the partially worn fasteners. Recently, Xia et al. [5] and Rubinsztejn [12] have successfully applied the AdaBoost algorithm to the fastener detection work. Specifically, Xia et al. [6] departed the hook-shaped fastener into four parts and each part was independently trained by AdaBoost. Thus, this method has the ability of detecting partially worn fasteners. Similarly, Li et al. [13] used image processing methods to detect the components of fastener.

However, these two methods can only handle specific fastener types and the robustness on illumination variation was not discussed. Other technologies that have been used for modeling and detecting fasteners include support vector machine (SVM) [14], Gabor filters [15], and edge detection [16]. In summary, most of the earlier methods take advantage of discriminative models (classifiers) to classify the fastener and non fastener samples, but it is difficult for them to identify the partially worn ones, because there is no uniform representation of the worn cases. Although, the part-based methods [5], [13] can solve this problem to some extent, they require multiple classifiers and can only handle specific type of fastener. On the other hand, to train classifiers, numerous labeled fastener samples including worn and intact fasteners must be collected.

However, the number of partially worn fasteners is very limited. Our method is designed for detecting the defects of various types of fastener and is able to find both the partially worn and the completely missing instances. Different from earlier methods, which rely on discriminative model, we solve this problem using generative model. Hence, the training stage requires only intact fastener samples. Meanwhile, our training set is unlabeled and composed of various fastener types, orientations and illumination conditions.

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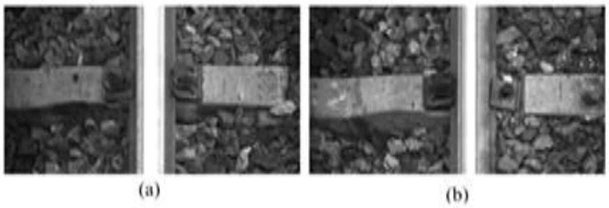
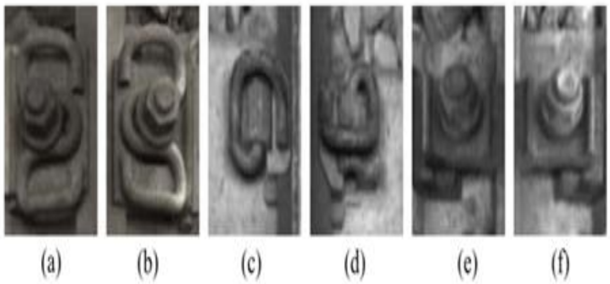


Worn and missing fasteners.
(a) Left fastener is partially worn. (b) Right fastener is completely missing.



Three types of fasteners. (a) Type-I left. (b) Type-I right. (c) Type-II left.
(d) Type-II right. (e) Type-III left. (f) Type-III right.

## SYSTEM OVERVIEW

The configuration of our system is shown in Fig. 5. There are two cameras hanged below a train coach, each of which monitors a side of track. The size of an acquired image is 560 × 900 pixels. An example of the acquired image is shown in Fig. 1. The image is sent to the onboard high-performance computers as the input of data processing module. The data processing module is composed of three major components: 1) fastener localization; 2) fastener classification; and 3) score ranking. The final results are summarized on an interactive user interface for further manual inspection and analysis. We show the flow chart of the data processing module in Fig. 6.

Overviews of these steps are given as follows.

- Fastener localization: Fasteners are permanently installed on each sleeper at both sides of a track. Therefore, the localization of fasteners can be replaced with the detection of sleepers and tracks. This detection is achieved by searching some specific geometric relations between line segments. To alleviate the computational burden, we predict the positions of fasteners based on the constant distance between two adjacent sleepers.
- Fastener classification: The image regions that contain fasteners are then transmitted to the classification module. In this module, the type of each test fastener is determined according to the learned models.
- Wear ranking: We rank the fasteners into three levels based on the likelihood probability, which measures the consistency between a fastener and the corresponding model. We show that the fasteners ranked into the low level are severely worn or missing, which need to be immediately replaced. Most of the fasteners ranked into middle level are partly worn. These fasteners require further assessment by human inspectors.

## FASTER LOCALIZATION

The positions of fasteners can be indirectly determined by the positions of sleepers and tracks. In this paper, we take advantage of the robust line segment detection algorithm and the geometric relationships to localize sleepers and tracks. We first introduce the track detection and sleeper detection algorithms and then describe a sleeper prediction approach, which considerably accelerates the detection speed and improves the robustness.

### A. Track Detection

In an acquired image, a track is viewed as a long rectangle vertically located nearby the middle of image. Mostly, it is overexposure due to the high reflection rate of the smooth track head. The detection of a track can be simplified to the detection of two longest vertical lines. First of all, line segment detector (LSD) [21] is used to extract lines. The vertical lines that close to the middle of the horizontal axis are preserved. Then, the pixel values are projected onto the x -axis to generate accumulated intensity histogram. Finally, the overlapped positions of the

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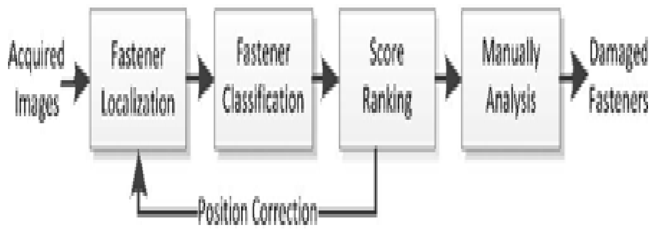
vertical lines and the sharp increasing or decreasing in the histogram are identified as the edges of the track.

## B. Sleeper Detection

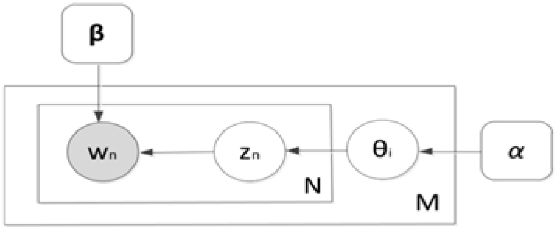
For most of the railway infrastructures, sleepers are symmetry with respect to the track and periodically arranged along the railway line. Therefore, the sleepers can be detected by simply searching the symmetrical line pairs at the same y-coordinate. This algorithm is composed of the following three steps.

- The LSD algorithm is performed on railway images to extract line segments. Only the horizontal lines are preserved.
- Among these lines, the parallel lines are identified. The distance between two parallel lines is not longer than the width of a sleeper. For our image, the maximum width of a sleeper is 180 pixels.
- For each pair of the parallel lines, if one or more corresponding parallel lines with the same y-coordinate can be found at the other side of the track, the region enclosed by these parallel lines is recognized as a sleeper.




Flow chart of the data processing module.

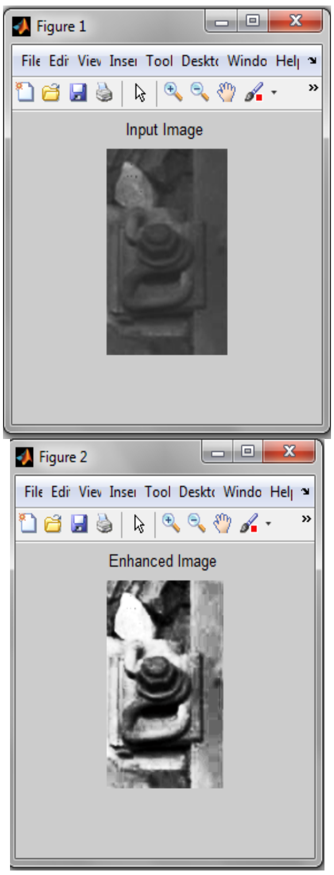
The position of a fastener can be predicted by simply adding Dy in terms of the position of the previously detected sleeper. As shown in Fig. 1, Dy is the constant distance between adjacent sleepers. In our implementation, Dy is initialized by performing sleeper localization algorithm for the first 100 frames, and then the positions of following sleepers are predicted in coming frames. The sleeper detection algorithm is also performed in every 500 frames to rectify Dy and prevent the accumulated error. Furthermore, Dy is recomputed when all the adjacent fasteners are given very low likelihood probabilities in the classification stage.




Graphic model representation for LDA.

## SIMULATION RESULTS

The fastener image is first taken. After that pre-process the image to remove any noise.




Input fastener image, Enhanced image

Image preprocessing, also called image restoration, involves the correction of distortion, degradation, and noise introduced during the imaging process.This process produces a corrected image that is as close as

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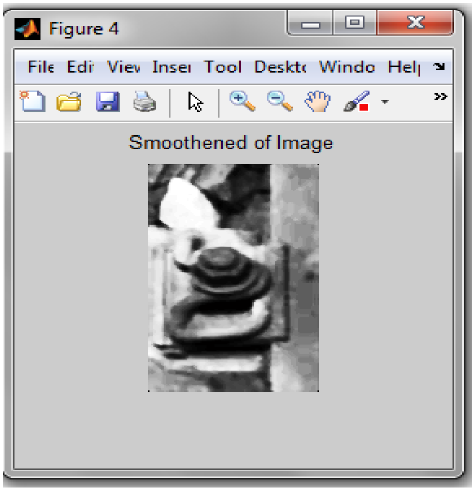
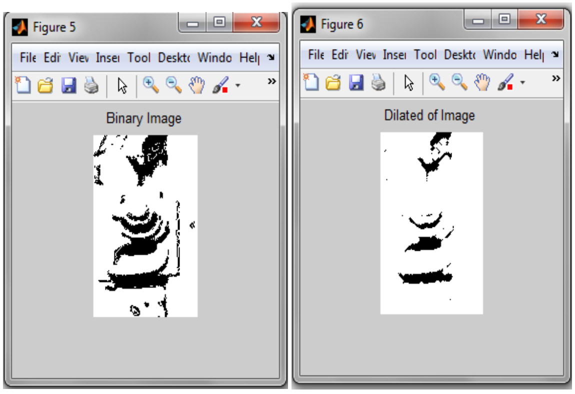
possible, both geometrically and radiometrically.The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers.



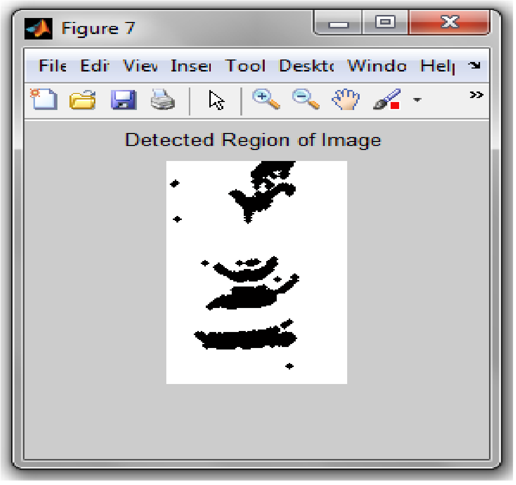

Smoothened image

Smoothing is to create an approximating function that attempts to capture important patterns in the data, while leaving out noise or other fine-scale structures/rapid phenomena. In smoothing, the data points of a signal are modified so individual points (presumably because of noise) are reduced, and points that are lower than the adjacent points are increased leading to a smoother signal. Apply Gaussian convolution and then apply median filter to get the smoothened image.



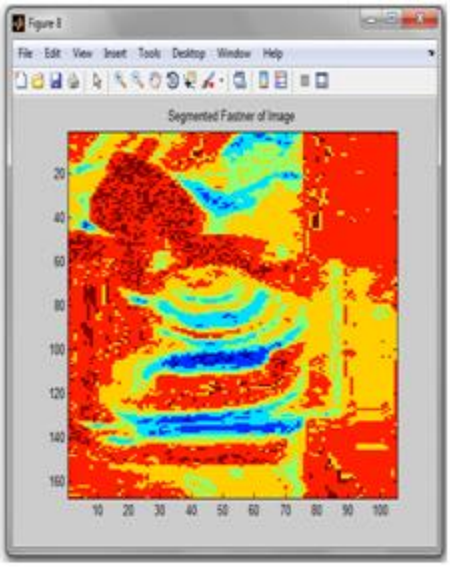

Binary image ,Dilated image

The binary image is shown in figure 5.4.. For Classification and other purpose, we have to get the binary image. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image. The basic effect of the operator on a binary image is to gradually enlarge the boundaries of regions of foreground pixels (*i.e.* white pixels, typically). Thus areas of foreground pixels grow in size while holes within those regions become smaller The structuring element that determines the precise effect of the dilation on the input image.




Detected region

The fastener information is present in the detected region of image. Segmentation partitions an image into distinct regions containing each pixels with similar attributes. To be meaningful and useful for image analysis and interpretation, the regions should strongly relate to depicted objects or features of interest.



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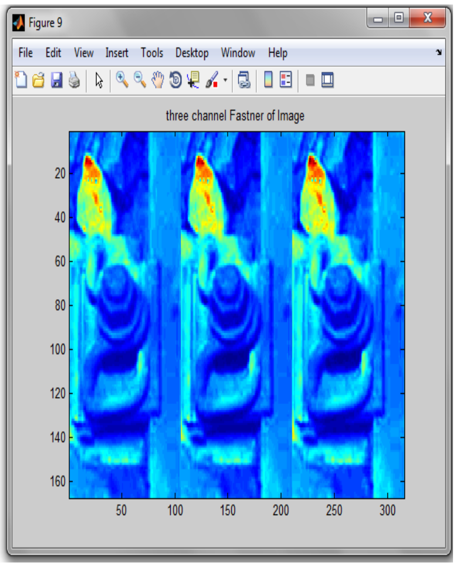
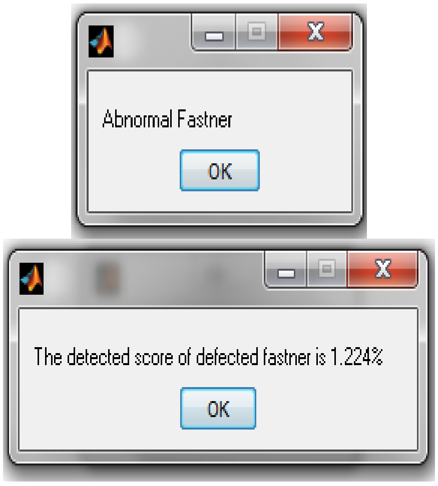



Segmented image, Three channel image

The fastener image is shown in three channels(rgb).we take input image as black and white image. So that all the channels are in same color.




Score ranking, Final condition of fastener

The score ranking dictates that how much the input image is damaged from the trained samples. Finally the fastener is in abnormal condition which is displayed on the screen.

## CONCLUSION

The detection of worn and missing fasteners is an important task in railway inspection. However, the manual inspection is of poor efficiency. On the other hand, the earlier automatic inspection systems based on classifiers are of low reliability.

In this paper, a novel railway inspection system is proposed, which is able to simultaneously assess the damage of multiple types of fasteners. Relying on the topic model, the proposed inspection system has the following three major advantages: 1) different types of fasteners can be simultaneously modeled using unlabeled data; 2) the system is robust to illumination changes; and 3) the statuses of fasteners are ranked. Technically, we introduce a new topic model named STM to model the structures of fasteners. Possibly, STM is the first probabilistic topic model aiming at representing object structure. By which, the modeling of diverse types of fasteners becomes much easier.

The detailed evaluation on railway lines is provided. The proposed method has very high performance on recognizing good fasteners as well as detecting worn ones.

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