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Pantograph Detection System using Image Processing Techniques[1]

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Abstract. We present image processing techniques for detecting the interaction between the pantograph and the catenary system of a tilting train. Due to the displacement of the contact point with respect to the reference position, an image processing analysis of each frame is performed by using the Hough transform in order to detect stagger of trolley wire automatically. The proposed approach is very efficient and produces desirable output data.

Keywords: Pantograph detection, Stagger detection, Trolley wire detection, Hough transform

1 Introduction

In order to satisfy the maintenance requirements and the safety features of the trains, a relevant objective for railway companies is to develop new techniques to continuously monitor the contact point where the overhead trolley wire and the pantograph of a locomotive meet. A catenary is a system of overhead wires which supply electricity to a locomotive, which allows electricity to travel by way of a pantograph. Catenary systems use at least two wires: a messenger wire or catenary which supports the contact wire with vertical drop or connecting wires. In the catenary, electrical current is supplied to the locomotive through the contact wire connected to the messenger wire by the hanger above. The catenary-pantograph system is a fairly complex system and several approaches have been taken to study the dynamics of the catenary and pantograph [1]. Several experimental trials have displayed that the main cause of damage to overhead contact line installations are caused by the short term thermal effect of the arcing [2,3].

We present image processing techniques for monitoring the pantograph and stagger of trolley wire for the safety of a titling train. Fig.1 shows the flowchart of the proposed stagger monitoring system. From the video sequence, we obtain still image size of 352 pixels by 240 pixels for applying image processing techniques. After registering the pantograph image as a template, the input image is scanned to find out the best matching position.

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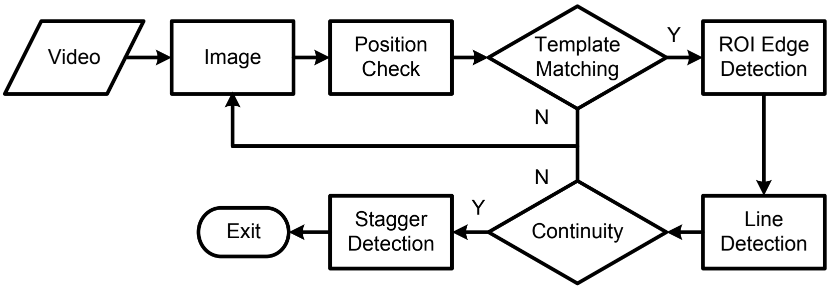

Fig. 1. Flowchart of the detection system

2 Detection System

One of the most fundamental means of object detection within an image field is by template matching, in which a replica of an object of interest is compared to all unknown objects in the image field. If the template match between an unknown object and the template is sufficiently close, the unknown object is labeled as the template object. However, a template match is rarely exact because of image noise, spatial and amplitude quantization effect, and a priori uncertainty as to the exact shape and structure of an object to be detected. An object is deemed to be matched wherever the difference is smaller than an established threshold value. Consequently, a common procedure is to produce a difference measure between the template and the image field. Also, we have to consider the processing speed to trace the template as fast as possible to avoid missing a pantograph's movement. We are interested in the contact point between the trolley wire and the top of the pantograph; we therefore only process the ROI rather than the entire input image to save computational time as well as to increase the accuracy of the process. Because the window size of the ROI is the same as the template, it should be approximately 140 pixels by 40 pixels, as shown in Fig. 2.

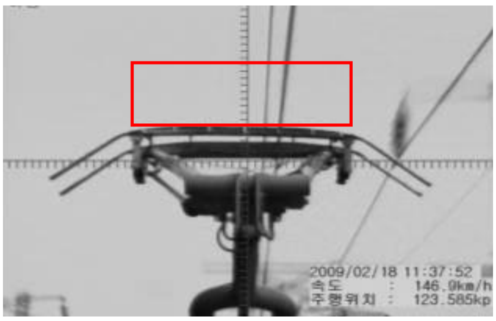

Fig. 2. Pantograph and Region of Interest (ROI)

The common difference measure is the MAD (Mean Absolute Difference) or MSE (Mean Square Error), but these measures are just comparing gray level difference. In order to keep up with the contact point of catenary-pantograph, we have to take into account the processing speed by keeping track of the template and the image field. To determine the accuracy of contact points during the matching process, we introduce the NCC (Normalized Cross-Correlation) that can detect the gray level by subtracting the average gray value from the original image, as given by Eq.(1) [4,5].

$$NCC = \frac{\sum_{i,j=0}^{M,N} O(i,j)T(i,j)}{\sqrt{\sum_{i,j=0}^{M,N} O^2(i,j)\sum_{i,j=0}^{M,N} T^2(i,j)}} \tag{1}$$

where M, N are sizes of the templates, $O(i,j) = o(i,j) - o'$, $T(i,j) = t(i,j) - t'$ and o, t are the part of image and the template with its averages o', t', respectively.

Due to many artificial structures near the catenary system such as truss beams and cross span elements, we are able to recognize the wrong contact points. However, using the motion vector information, we can estimate the movement of contact points between the pantograph and the trolley wire. If a contact point is out of range from the previous detected ones or moved to an opposite direction with the respect to the motion vector of the frame, we may omit the point from the detected position if it is not the moment of changing direction. An example of the motion vectors using the 5 pixels by 5 pixels blocks is shown in Fig. 3, where motions are displayed as vectors indicating location, orientation and scale. We applied the block-matching motion estimation process to detect the motion vector. The block-matching motion estimation is one of the most important modules in the video sequence process. It divides image frames into equal sized non-overlapping blocks and measures the displacement of the best-matched block from the previous image frame as the motion vector of the block in the current image frame within the search window. To improve the search time on the block matching process, many simplified and efficient block matching algorithms for fast motion estimation were proposed [6].

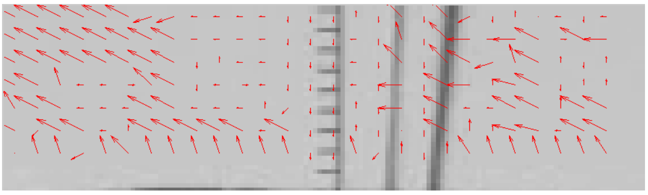

Fig. 3. An example of motion vectors of ROI

The trajectory examples from video frames 500 to 1000 are shown in Fig. 4. It shows three dimensional image of the vertical position of the pantograph and the stagger of the trolley wire, where the circles represent the left side of the staggering movement from the center and the cross symbols show the right side of the staggering movement from the center.

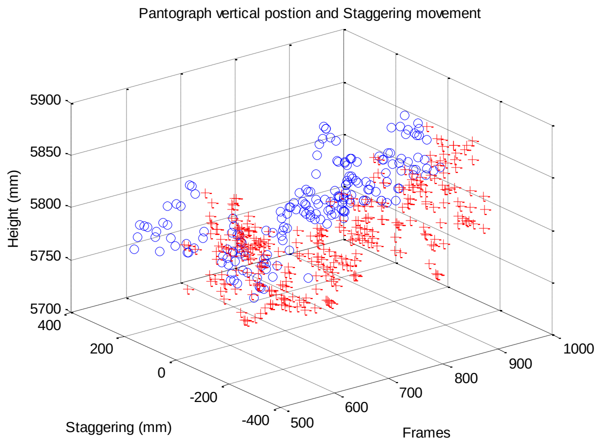

Fig. 4. 3D trajectory of vertical position of the pantograph and its staggering movement

3 Conclusions

We applied the image processing techniques for monitoring the pantograph height and stagger of trolley wire and experimentally verified the safety of a tilting train since the variations of pantograph height and stagger of trolley wires are within a certain safety range. The pantograph height should range from 5200 mm with a variance of 250 mm and the stagger of the trolley wire should be with a variance of ± 200 mm for safety purposes. The proposed approach did not only significantly improve the computational time and performance of detecting stagger, but also produced much more accurate output data. The process for detecting several trolley wires and discriminating between trolley wires and messenger wire is still ongoing.

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