DEVELOPMENT OF A RAILROAD TRACK INSPECTION SYSTEM BASED ON VISUAL PERCEPTION USING LABVIEW

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Abstract

Railroad track inspection is essential to guarantee safe operation condition for the rails to travel on. Even though railway sector invests hefty costs, time and strong human workforce to ensure the performance and safety of the railroads, frequent accident occurs throughout the year due to poor visual inspection carried out by the human inspectors. The quality of inspection remains a question mark and deteriorates progressively when the experienced human inspectors are made to carry out the inspection all along the railroads exposing them to mental fatigue and other potential health hazards. Therefore, in this study, a simple method using visual perception and image processing techniques for the inspection of railroad track for anomalies is presented as an alternate solution to the traditional inspection system. An automated wheeled mobile robot is also prototyped to carry out the inspection on the railroads. This prototyped system uses a visual perception algorithm based on edge detection and feature extraction is developed in LabVIEW, which continuously records the images of the track; assesses and detects the railroad components such as loose bolts, bent bolts and surface cracks, which are very critical for rail safety. The performance of the proposed system is investigated in the laboratory conditions and results show high performance in the detection of railroad track anomalies.

Keywords: Railroad Track Inspection, Visual Perception, Mobile Robot, Image Processing, Image Analysis

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I. Introduction

Railroad track inspection is essential to guarantee safe operation condition for the vehicle to travel on. Frequent inspection schedule, low maintenance and operating cost are the key factors contributing to the railroad inspection sector [XVII]. In order to achieve this, railway sector invest numerous resources which include time, money and workforce to ensure the performance and safety of the railroads. A railroad track is composed of a parallel set of rails at a specified distance connected to the sleepers on the ground with the help of clips, ties, switch rods, bolts, heels and joint bar bolts surrounded by ballasts. These components would frequently appear throughout the railroads. These repeating components are similar but not identical to each other due to various manufacturing differences and environmental conditions. Railroads are vital in the development of infrastructure of most countries; however the inspection tasks are performed manually by a human inspector in a developing country like India.

Even though railway sector invests hefty costs, time and strong human workforce to ensure the performance and safety of the railroads, frequent accidents occurs throughout the year due to poor visual inspection carried out by the human inspectors. The quality of inspection remains a question mark and deteriorates progressively when the experienced human inspectors are made to carry out the inspection along the railroads carrying heavy tools exposing them to mental fatigue and other potential health hazards. As a result, precious lives were lost and reason to the accident such as derailment of trains, were caused by poor inspection process done on the railroad track which can be improved. The derailments of trains are the most frequent and major causative accident types in Indian Railways. According to the Indian Ministry of Railways, there are a total of 2045 derailments were occurred in Indian Railways during 2000-2016, with an average of 128 accidents per year [XX]. Hence there is a need for more reliable and improved rail flaw detection systems due to more stringent maintenance requirements levied by the Railway Board of India.

In recent years, researchers focus on use of technical advancements for the automated inspection of railroad track inspection techniques. By the automated technologies, the inspection process can be done more efficiently and this can reduce the chances of accidents on railroad track. Non-Destructive Evaluation (NDE) methods utilizing different sensors such as X-ray, ultrasounds, are adapted to inspect the rail systematically [VI]. In most cases rail inspection is performed using special ultrasonic probes mounted on the undercarriage of the test train. Magnetic Flux Leakage (MFL) testing is usually employed for the detection of near-surface defects as complementary technique to ultrasonic testing [XXIII]. Other NDE techniques that are currently under investigation for high-speed inspection of rails includes laser-ultrasonic [XXI], Electromagnetic Acoustic Transducers (EMATs) [VIII], Alternating Current Field Measurements sensors (ACFM) [XII], advanced multi-frequency eddy current sensors [XXIV], Field Gradient Imaging (FGI), high-resolution ultrasonic probes, ultrasonic phased arrays, and long range ultrasonic [VII]. Most of these techniques have been already developed enough to be used in portable systems for the inspection of rails at lower speeds, and should possess a good lift-off control. Each of the above
techniques is designed to detect certain types of rail track damage and wear has its own advantages and disadvantages.

The use of alternative techniques for manual inspection such as machine vision is more straightforward to implement and can provide increased accuracy. Machine vision [I], [V], [XII], [XVI] a part of NDE, utilizing visual perception, segmentation, feature extraction and defect assessments, has been developed in recent years with the great progress of computer vision techniques. In many contexts visual inspection is considered as suitable inspection techniques to detect anomalies of the railway tracks in critical situations [III], [IV], [XI], [XVI],[XXII]. Surface defects are one of the anomalies along with the conditions of the clips, ties, bolts etc. that the visual inspection techniques can detect throughout the railroad tracks, with high speed and accuracy[II], [X].

In literatures, studies have been made on image analysis, where most of the work is related to tunnel inspection through video logging [XVII], surveillance applications [V] or understanding human judgment through eye tracking of railway drivers [IX]. Singh [XI] and Mazzeo [XVI] proposed methods for inspection on fastening devices installed to the sleepers of the railroad track. However, no image based algorithm inspects any features installed at the side of the railroad track.

A visual perception method for detection, segmentation and defect assessments of periodically occurring track components such as ties, switch rods, bolts, heels and joint bar bolts is presented in [XV]. Three different algorithms, one for component detection, one for turnout detection and one for tie detection had been reported. However, the major drawback of this approach is that it is not possible for automatic detection and segmentation of periodically occurring components. An automatic vehicle to inspect the railroad track using vision-based algorithm is prototyped and illustrated in [XIX]. The anomalies detected were weld issues, squats, and interior imperfections along with head checks. An inspection vehicle with camera and signal processing units were designed and made to capture the video which is sent to the control unit located remotely. The video were converted into images and it is processed using MATLAB and the faults were analyzed. Even though a system is developed and qualitative analysis is performed there are no concurrent evident to prove the effectiveness of the system quantitatively.

A machine vision method to determine the anchor and ties on the railroad is proposed in [XVIII]. A control method is proposed to detect faults of tie plates are presented in [XI]. 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 qualitatively. Similarly, surface crack detection in railway tracks using image processing is addressed in [II]. This vision based system, grabs the images of the railroad tracks and compare with the existing database of non faulty images on continuous basis. Canny edge detection and Hough transform were used to detect the edges and extract the features of the rail surfaces for detecting anomalies. However, the increased computational cost and time delay were the major drawback which affected the system performance in real time implementations. A computer vision-based condition monitoring is proposed in

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A camera is placed on top of the train for image acquisition. On the acquired images, edge extraction, morphological processing and feature extraction methods are applied. Then, the several faults between the rails results are obtained. However, the lack of both qualitative and quantitative results, made it difficult to realize the effectiveness of the proposed methods.

Even though, the visual inspection system, utilizing the camera’s for perception and image processing techniques for the detection of anomalies of railroad tracks were addressed in the literature in recent years, this work focuses on developing a simple method and integrating the technique along with a mobile prototype for the detection of surface defects of the railroad tracks. This work describes the design of a autonomous inspection system travelling on railroad track and explores the application of image processing and vision based algorithm for detecting the features of anomalies such as surface cracks, loosen bolts and bend bolts installed on the sides of the railroad track for fastening. Visual perception algorithm based on edge detection and feature extraction using linear filters, canny edge detection and caliper functions is developed in National Instruments LabVIEW [XIV], [XV] – Image Acquisition tool kit and IMAQ platform to detect the features of the anomalies. Experimental investigations are carried out to measure the performance of the developed method, where bent and loosen bolts are detected and the distance of cracks found on the railroad track is measured against distance of cracks obtained from the vision based algorithm respectively, to prove the effectiveness of the method addressed in this work.

The organization of this manuscript is as follows. Section II, discusses the overview of the system and prototype design. Section III briefly describes the image processing algorithms developed in NI-LabVIEW for the detection of railroad track anomalies. Section IV describes the experimental investigations which are carried out to measure the performance of the developed method quantitatively along with the results. Finally, section V concludes the outcome of this work and details the scope for further improvements and future directions.

II. System overview

As discussed in the previous section, the anomalies that are interested in detection are surface cracks, loosen bolts and bend bolts repeatedly present in the railroad tracks. An Image processing algorithm based on visual perception is developed in LabVIEW environment and used for detection of such anomalies. The detection of such anomalies is important for maintenance because it provides information on the condition of the railroad tracks and poses potential threat to degrade the safety of the railroad tracks. The image processing algorithm developed emphasis on the detection of surface cracks and the condition of bend and loose bots used to fasten the tracks which are mounted on the sides of the railroads. A high-resolution web cam is used to capture the images of the track and positioned over an adjustable stage mechanism, which slides and position the camera on either side of the railroads. The acquired image is then converted into enhanced grayscale images, and the features of the bolts and cracks are identified using simple edge detection in LabVIEW image processing tool box.
Features such as the distance of the bolt head with respect to the rails in terms of loosening of bolts, angle of bending of bolt shaft with respect to the rails, crack thickness on the rail surface are the features of the anomalies that are identified using edge detection techniques. Then the conditions of the railroad track are analyzed based on the extracted features. In this case, when the features of the loose bolts are identified, degree of slack is measured and displayed to make a decision on the condition of the track. Similarly, as for the bend bolts, the angle of bend is measured and displayed. Cracks appear as a black line on the acquired image which is the Region of Interest (ROI). By using the difference in the intensity of the gray scale values over the black line and the rails, these cracks are identified. As the features of the cracks and bolts are identified, the distance of the features with respect to the robot frame is obtained.

High resolution webcam as visual perception system is installed over a wheeled mobile robotic platform which travels over the rails and guides designed as shown Fig. 1. A scaled down railroad track is assembled by using L-Shape aluminium bars and provides a platform for the robot to travel on. Besides that, bolts and cracks were simulated on this platform to allow the vision perception to carry out the inspection process. The bolts are repeatedly fastened between a distance of 15cm and the slack and bends are induced as shown in Fig. 1.

![Scaled down Railroad Track](image)

**Fig. 1 Scaled down Railroad Track**

Fig. 2. Shows the developed mobile robotic platform with sliding mechanism and webcam. The platform is made up of a plastic chassis with 4 guided wheels and with dimensions of 37cm x 19cm x 8 cm. The wheels are with flanges on the side of the wheels are to mimic the train wheels. The platform is driven with a single drive train comprises of a planetary DC geared motor with 50 rpm and has the enough torque for locomotion. The chassis and wheel assembly are connected with a suspension system to suppress unnecessary vibrations during travel resembling the bogies of the train. A 3mm Aluminium sheet is mounted over the chassis to have the slider mechanism and robotic controllers and motor drivers.
A rail and a guide as shown in Fig. 2 are installed to equip the robot with the slid scan facility. The rail and guide is a linear guide obtained from a malfunction inkjet printer driven by a stepper motor and belt assembly, which positions the camera on either side of the tracks. This inspection system is powered by a battery pack of 7.2V Ni-Cd battery. The robot is driven at a speed equals to the frame acquisition rate of the camera, enabling the inspection system to acquire clear images of the interested anomalies of the railroad track. Localization of the mobile platform is obtained by odometry technique. A combination of IR sensor and white patch on the rear wheel forms a simple encoder which measures the rotational speed of the robotic platform. An ATmel MCU ATMEGA 16U2 development platform is used as the controller for the railroad inspection system and controls the motion of the slider and the robot itself.

III. Methodology

As mentioned in the previous session, the objective of visual perception (image processing) algorithm is to detect loose bolts, bent bolts and surface cracks in the railroad tracks and thereafter identify whether they are faulty. National Instruments LabVIEW Vision Assistant platform and IMAQ vision acquisition is used to devise the vision based algorithm that detects anomalies of the railroad track. Labview Vision Assistant is a tool for prototyping and testing image processing applications. NI Lab View is chosen to be the image-based algorithm software platform is because the user can benefit from increased productivity with graphical programming and visual algorithm engineering using NI vision software. A configurable environment and comprehensive programming libraries can be chosen throughout the development. Besides that, interfacing with the vision perception is possible because the NI Vision Acquisition Software package offers optimized drivers for industry-standard camera interfaces and, with LabVIEW drivers for specialty cameras. This allows the user flexibility to alter or change the hardware in future. Fig. 3 illustrates
the step by step procedure for processing the images perceived continuously by the camera to identify the rail road track anomalies

![Image Processing Diagram]

**Fig. 3 Overview of Image processing algorithm**

The process flow of the developed algorithm is as follows and the pictorial representation is given in Fig. 4.

**STEP1.** Obtain the image of the railroad through Webcam.

**STEP2.** Convert the acquired image to grayscale by plane extraction function.

**STEP3.** Filter the image to enhance the feature of the anomalies. IMAQ convolute function is used for this purpose.

**STEP4.** Define the Region of Interest (ROI) on the Image.

**STEP5.** Detect the edges using a simple edge detection function present in vision assistant, which utilizes change in grayscale values of the adjacent pixels.

**STEP6.** Find the coordinates of the edges in the ROI

**STEP7.** Caliper function in the vision assistant is used to measure the pixel distance between two edge coordinates.

**STEP8.** Estimate the real distance with respect to robot frame from the pixel distance using the following empirical relationship

\[ y = 17.557e^{0.0077x} \]  

where, \( y \) is the real distance estimated and \( x \) is the pixel distance obtained by image processing.

The main image–processing step in the detection of bolts and cracks include the operation of convolution of image and edge detection. In image processing, the image obtained undergoes a transformation in order to allow feature extraction of its
intrinsic feature. First, the image obtained is in RGB format from the camera. This 32-bit RGB is then converted into 8-bit grayscale image using a plane extraction function, in which the color image data in an array of unsigned 32-bit integers is converted into Hue Saturation and Luminance (HSL) plane. The luminance plane corresponds exactly to the grayscale image and furthermore, it is the only color plane that gives an accurate representation of the grayscale image [XI]. The grayscale image is then enhanced with Image Convolution - general purpose linear spatial filter used to filter the image. IMAQ Convolute is used as a convolution kernel, which enhances the quality of the image in the grayscale by filtering the noises present in the image using linear filters. Linear filter replaces each pixel by a weighted sum of its neighbours and yields smooth, sharpen, and transform form of an image so that the information such as detecting edges along a specific direction, contouring patterns etc. is extracted. Fig. 5 shows the processed image where the edges in the image are enhanced for further processing.

After enhancement, features of the railroad track stands out. After this, Region of Interest (ROI) is set on the surface of the railway track. A region of interest (ROI) is an area of an image in which the image analysis is performed. First step in the analysis is the detection of the edges in the image. An edge is defined as a significant

Fig. 4: a) Grayscale converted Image b) Filtered and enhanced Image c) Region of Interest (ROI) d) Edge detection e) extraction of edge coordinates using caliper f) Detection of Loose Bolt

Fig. 5. (a) Image before convolution (b) enhanced image after convolution.

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change in the grayscale values between adjacent pixels in an image. Canny edge detection is used as the edge detection method, where the change of intensity of grayscale value along the line formed on the ROI is used for edge detection. Relative threshold amongst the pixel is used to determine the change in pixel values to be considered as an edge. Falling edge negative polarity is applied in this as the search direction is from a higher grayscale value to a lower grayscale value. Along the ROI, the railway track is in a higher grayscale value, if an anomaly is detected the grayscale value drop to a lower value. Therefore, a falling edge is detected. This process will repeat to search for the rising edge. When both edges are found on the ROI, the detection of edges is performed as shown in Fig. 6.

![Fig. 6 Bolt Profile Detected Using Edge Detection](image)

IV. Experimental Investigations

In this section the quantitative results that are obtained to measure the performance of the developed inspection system is presented. Performance of the system is measured through experimental studies which detects the anomalies of loose bolts, bent bolts and surface cracks. The pixel values obtained as the result of image processing is converted into distance values using the empirical relationship given in equation 1. Then the accuracy of the system is tested against the real positional measurements of the anomalies with respect to the railroad’s and robotic vehicle. Fig. 7 shows the algorithm developed in LabVIEW using IMAQ Vision Assistance.

IV.a. Detection of Loose Bolts

As mentioned earlier section, the Region of Interest (ROI) / well defined area is set the acquired, enhanced and processed image, where the bolts appear on it. The bolt head is detected as a feature, a line of reference is placed on the head of the bolt until the edge of the surface of the railway track. The edge detection function detects the edges of the bolts and railroad surfaces in the ROI, by analyzing the change in intensity of the grayscale values. The key aspect to be considered is the difference in the grey scale values of the bolt and the railroad track surface, as the bolt appears as the dark shade with respect to the surface of the railroad track. It could be found from Fig. 8, that the bolt head in the ROI has lower grayscale value when compared to the surface of the railroad track. Once the edges of the bolt head and railroad track and its respective coordinates are
Fig. 7. Extraction of Bent Bolts, Loose Bolts and Surface Cracks in LabVIEW

Fig. 8(a) Use of caliper to estimate the looseness of the bolt with the surface of the railroad track (b) Experimental platform designed to measure and differentiates the loose and tight bolts.

identified, Caliper function in vision assistant toolbox of LabVIEW, measures the pixel distance between the bolt head and the surface of the railroad track, to determine how loose the bolt is as shown in Fig. 8. differentiates the loose and tight bolts.

Therefore, when the bolt is tightly fastened with the railroad track surface, the distance measured will be least value and when it is slack the distance will be a largest value in terms of pixels. For easy understanding, the steps involved to differentiate the loose and tight bolts are illustrated in Fig. 9 (a). Fig. 9 (b) shows the experimental results that are obtained as a performance measure of the developed algorithm to detect the looseness of the bolts. Estimated values are the values obtained from the image processing algorithm and real values are the

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measure of looseness of the bolts using a vernier caliper manually. The inaccuracy in the measurement using the visual perception method is found to be less than ±6% in laboratory conditions.

![Flowchart](image)

**Fig. 9** (a) Flowchart representing the method utilized for detection and differentiation of loose and tightly fastened bolts. (b) Estimated separation distance w.r.t real separation distance of the algorithm detecting loose bolts.

**IV.b. Bent bolts**

Fig. 10 (a) illustrates the steps involves in the determination of bend bolts in the railroad tracks. To detect bent bolts, a ROI is defined on the acquired and enhanced image where possible bend can appear. Features of the bolts are detected using edge detection. Angle of the bolt is then measured against the horizontal line of the image using a simple trigonometric relationship as shown in Fig. 10 (b). Fig. 11(a) represents the positions of the bended bolts along with the normal bolts that are arranged in the railroad under investigation. These bolts are cold bended and manually fastened in the railroad prototype platform.

Fig. 11(b) illustrates the experimental results that are performed to measure the performance of the developed algorithm for the detection of bend bolts and angle of bend. It also presents a tight correlation exists between the estimated angles of the bend using visual perception against the real bend angle of the bolts with an inaccuracy of ±10%. The condition of the bolts will be displayed in the graphical user interface of the developed algorithm as “the bolt is fine” and “the bolt is bent” during investigation. The major drawback with the developed algorithm is that the
detection of the bend bolts is not possible when the bending angle of the bolt is not visible to the webcam.

**Fig. 10(a)** Flowchart representing the method utilized for detection and differentiation of loose and tightly fastened bolts. **(b)** Estimation of bend angle of the bolts in vision assistant.

**Fig. 11 (a)** Positions of Bend Bolts in Railroad under investigation. **(b)** Estimated angle of bending in bolts w.r.t real bended angle of the bolts under investigation.

### IV.e. Surface Cracks

The steps used in the development of visual perception algorithm are illustrated in Fig. 12 (a). The cracks are induced in the form of thick and thin black lines using permanent markers in the surface of the developed railroad prototype. As mentioned in the previous sections, the difference in the grayscale pixel values between the surface and crack region is used as a feature to identify the cracks. For this, ROI is defined in the processed image as shown in Fig. 12 (b). Then an edge detection function detects the edges of the cracks and its coordinates. Once the coordinates are

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found, the pixel values between the edge of the crack and datum are measured by keeping the robot current posture as the datum. Then these pixel values are converted into the estimated distance by using equation 1. This results in the location of crack on the railroad with respect to the robot and it is displayed on the vision assistant display as shown in Fig. 13 (a).

![Flowchart representing the method utilized for detection surface cracks in railroad track. (b) ROI of cracks on surface of railroad track](image)

**Fig. 12 (a).** Flowchart representing the method utilized for detection surface cracks in railroad track. (b) ROI of cracks on surface of railroad track

**Fig. 13(a).** Display of crack position w.r.t robot in LabVIEW Vision Assistant. **(b).** Experimental results of estimated distance against the actual distance of the railroad surface cracks.

The results obtained as the performance measures are shown by Table 1 and Fig. 13(b). It is evident from the results that the estimation of the location of crack in
the surface of the railroad track by the visual perception method shows a good correlation between the estimated and actual distance with the inaccuracy of less than \( \pm 8\% \). From fig 16 it is observed that a thicker crack is fairly visible compared to a thin crack. Therefore, it is also observed that the thickness of the cracks also plays a vital role in the performance of the developed algorithm. Crack thickness less than 2mm is undetectable due to the resolution of the camera. The performance of the algorithm could be improved while using a high-resolution camera. Further, the ambient light also affects the performance of the development systems.

**Table 1** Estimated distance vs the actual distance of the surface crack in the railroad track

| Actual Distance (cm) | Pixel Distance (pixel) | Estimated Distance (cm) | Percentage error (%) |
|----------------------|------------------------|-------------------------|----------------------|
| 20                   | 17.81                  | 18.27                   | 8.7                  |
| 25                   | 43.9                   | 27.52                   | 10.1                 |
| 30                   | 71.02                  | 33.74                   | 12.5                 |
| 35                   | 93.03                  | 36.96                   | 5.6                  |
| 40                   | 105.12                 | 39.48                   | 1.3                  |
| **Average error (%)** | **7.64\%**             |                         |                      |

When the ambient light is too low, vision system is unable to acquire a clear image of the railroad tracks, and the interested features are distorted in the acquired image. When features are not extracted, the image based algorithm fails to process the image obtained. In addition, the Image obtained is also affected by the iridescent of the refresh rate of the vision system. This causes noise to be induced to the acquired image. Results of the image based algorithm are affected because of this iridescent. Proper filtering process could be implemented in order to remove the flickering of image as image obtained is a stable data and image processing can be done efficiently.

**V. Conclusion**

An autonomous inspection system based on visual perception and image processing for detecting the features of anomalies such as surface cracks loosen bolts and bend bolts installed on the sides of the railroad track for fastening is developed and addressed in this work. A mobile robotic platform is also developed and used as a system to provide the mobility for the inspection system to inspect the anomalies present in the railroads. A computationally simple vision based algorithm is developed in LabVIEW, which continuously record the images of the track; assess and detects the railroad components such as loose bolts, bent bolts, and surface cracks. A prototype rail road is also designed and several anomalies such as cracks
bend and loose bolts are induced in the system to measure the performance of the developed system. The effectiveness of the developed algorithm is experimentally investigated in laboratory conditions and results show high performance with positional inaccuracy of the estimation is found to be less than ±6% to ±10% while detecting the surface cracks, loose and bend bolts. Our future work is directed towards the improvement of the effectiveness of the proposed system by incorporating more a constant light source on the robot vehicle, utilizing a high resolution camera and advanced image processing and feature extraction methods to detect the anomalies. Several other anomalies generally present in the railroad tracks such as the ties, fish plates, and internal surface cracks of the rails also to be investigated by combining visual perception with other sensing methods. Thus our focus is on developing a fault tolerant autonomous inspection system for the inspection of railroad tracks.

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References

I. A. Distante, M. Nitti, E. Stella, P. L. Mazzeo, and F. Marino, “Automatic method and system for infrastructure visual inspection,” International Patent N. WO2007/010473, owned by the Italian National Research Council. World Intellectual Property Organization (WIPO), January 25, 2007 (International Filing Date: July 17, 2006; Priority Data: RM2005A000381, July 18, 2005).

II. A. Raza Rizvi, P. Rauf Khan, S. Ahmad., “Crack Detection in Railway Track Using Image Processing”, International Journal of Advance Research Ideas and Innovations in Technology, Vol.: 3, Issue: 4, pp. 489-496, 2017.

III. E. Resendiz, J. M. Hart and N. Ahuja., “Automated Visual Inspection of Railroad Tracks”, IEEE transactions on Intelligent Transportation Systems, Volume: 14, Issue:2, pp. 751-760, 2013.
IV. E. Resendiz, L. Molina, J. Hart, J. Edwards, S. Sawadisavi, N. Ahuja and C. Barkan, “Development of a machine vision system for inspection of railway track components”, in Proceedings of the 12th WCTR World Conference on Transport Research, Lisbon, Portugal, pp. 3355, 2010.

V. G. L. Foresti and C. S. Regazzoni, “New Trends in Video Communications, processing and Understanding in Surveillance Applications”, Proc. International Conference on Image Processing, Vol.: 89, Issue: 10, pp. 1355–1367, 2001.

VI. H. Berger, “Non-Destructive Testing of Railroad Rail”, Transportation Research Record, Vol.: 744, pp. 22-26, 1980.

VII. Innorack, D4.4.1, “Rail Inspection Technologies”, Project no. TIP5-CT-2006-031415, Available at: www.innorack.net.

VIII. J. L. Rose, M. J. Avioli, P. Mudge and R. Sanderson, “Guided wave inspection potential of defects in rail”, NDT&E International, Vol.: 37, pp. 153-161, 2004.

IX. K. Itoh, H. Tanaka and M. Seki, “Eye Movement Analysis of Track Monitoring patterns of Night Train Operators: Effects of Geographic Knowledge and Fatigue”, in Proceedings of the IEA 2000/HFES Congress, pp. 360-363, 2000.

X. M. Karakose, O. Yaman, M. Baygin, K. Murat and E. Akin, “A New Computer Vision Based Method for Rail Track Detection and Fault Diagnosis in Railways”, International Journal of Mechanical Engineering and Robotics Research, Vol.: 6, Issue: 1, pp. 22-27, 2017.

XI. M. Singh, S. Singh, J. Jaisal and J. Hempshall, “Autonomous Rail Track Inspection using Vision Based System”, IEEE International Conference on Computational Intelligence for Homeland Security and Personal Safety, pp. 56 – 59, 2006.

XII. M. P. Papaelias and M. Lugg, “Detection and evaluation of rail surface defects using alternating current field measurement techniques”, Proceedings of the IMechE Part F: Journal of Rail and Rapid Transit, Vol.: 226, Issue: 5, pp. 530–541, 2016.

XIII. NI IMAQ Vision Assistance Tutorial [Online] Available: https://neurophysics.ucsd.edu/Manuals/National%20Instruments/National%20Vision%20Assistant%20Tutorial.pdf

XIV. NI IMAQ Vision Manual [Online] Available: http://www.csun.edu/~rd436460/Labview/IMAQ-Manual.pdf

XV. NI Labview IMAQ Vision Concept Manual [Online]. Available: http://www.ni.com/pdf/manuals/322916b.pdf

XVI. P. L. Mazzeo, M. Nitti, E. Stella and A. Distante, “Visual Recognition of Fastening Bolts for Railroad Maintenance”, Pattern Recognition Letters, pp. 669 – 677, 2004.
XVII. P. Yarza, A. Amirola, “New Technologies Applied to railway Infrastructure Maintenance”, Meeting on Planning, Design, Construction and Equipment of Metropolitan Railways, Madrid, 2003.

XVIII. R. A. Khan, S. Islam and R. Biswas, “Automatic Detection of defective rail anchors”, in Proc. IEEE 17th Internal Conferences on Intelligent Transportation Systems, pp.1583-1588, 2014.

XIX. R.K. Verma, A.Jeewan, S.Jain and M.Vats, “Automatic Railway Track Inspection for early warning using Real time image processing with GPS”, International Journal on Recent and Innovation Trends in Computing and Communication., Vol.:3, Issue:10, pp. 5880 – 5883, 2015.

XX. S. B. Aher and D. P. Tiwari, “Railway Disasters in India: Causes, Effects and Management”, International Journal of Reviews and Research in Social Science., Vol.: 6, Issue: 2, pp. 122-130, 2018.

XXI. S. Kenderian, B.B. Djordjevic, D. Cerniglia and G. Garcia, “Dynamic railroad inspection using the laser-air hybrid ultrasonic technique”, Insight, Vol.:48, Issue: 6, pp. 336-341, 2006.

XXII. S. Sawadisavi, J. Edwards, E.Resendiz, J. Hart., C. Barkan and N. Ahuja., “Development of a machine vision system for inspection of railroad track”, in Proceedings of the American Railway Engineering Maintenance Way Association Annual Conference, 2009.

XXIII. Y. Li, J. Wilson, and G.Y. Tian, “Experiment and simulation study of 3D magnetic field sensing for magnetic flux leakage defect characterization”, NDT & E International, Vol.:40, Issue.: 2, pp. 179-184, 2007.

XXIV. Z. Liu, A.D. Koffman, B. C. Waltrip and Y. Wang, “Eddy Current Rail Inspection Using AC Bridge Techniques”, Journal of Research of the National Institute of Standards and Technology, Vol.:118, pp.140-149, 2013.