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A Comparative Study of Traditional Methods of Train Detection and Innovative Approaches Using Image Processing

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ABSTRACT

This research paper conducts a comprehensive analysis of train detection methods, comparing traditional systems with proposed alternatives i.e. Image Processing. The primary objective is to address the critical need for accurate train detection in railway operations while considering the cost-effectiveness and feasibility of implementation. Traditional methods, such as track circuiting and axle counting, are examined for their characteristics, instrumentation, and costs. In contrast, the proposed methods leverage modern technologies image processing, aiming to provide reliable and economical alternatives. The study includes a detailed exploration of the operational characteristics, requirements, applications, costs, limitations, and potential improvements for each method. The comparative analysis evaluates factors such as ease of operation, cost-effectiveness, level of risk, complexity of integration with existing systems, and overall system cost. The findings aim to guide railways in choosing suitable and efficient train detection methods, considering their specific operational needs and budget constraints. The research concludes with recommendations for implementation and suggestions for future developments in train detection technology.

KEYWORDS: Railway, Train Detection, Track Circuits, Axle Counters, Image Processing.

1 INTRODUCTION

While operating trains on any type of rails, the single most important information is that where is the train at given particular moment. Since the inception of railways, there have been many methods in use to detect and ensure the presence of the train over the track. Based upon the characteristics of the rails, trains, wheels and several other parameters, trains are detected in different manners. The most primary method which was used to detect trains is undoubtedly the human eye. Even in modern days such as today the human eye is used to detect the train in several parts of the world. With the passage of time as the technology evolved the train detection methods have improved.

In order to detect anything in general and trains in particular the characteristics of the specimen in question (`onwards trains) are first listed. The characteristics of the trains (Operational) are given in table 1.

Table 1: Characteristics of Track and Rolling Stock

Sr#	Description of Item	Characteristics	Instrumentation and measurement technique	Application
1	Track	Metal	Can be electrified overall or in portions	Track Circuits
		Continuous	Running trains produce sounds when on rails.	Acoustic Noise Distribution
		Essential component		
		Fixed location		
2	Rolling Stock and Locomotive	Wheels	Wheels electrically shunt the track	Wheels and axle counters
		Axles	Wheels and axles can be counted	Bogies and wagons can be counted
		As whole Unit	As whole the rolling stock can be counted	Bogies and wagons can be tagged with RFID
		Wheels and axle as continuous metal		Start and end of the train can be detected by RFID
				Start and End Of the train can be ensured with the use Image Processing

A Locomotive is always marshaled at the beginning of the train, hence can be utilized for detection of train. Likewise, the detection of train is also done using axle counters and track circuits over track lengths and Brake Van like Locomotive is always at the rear end of the train can also be used for the detection of train. A typical locomotive, track and brake Van are shown in the figure 1.

Figure 1: Locomotive, Railway Track and Brake Van

Table 2: Detection methods currently enforced in Pakistan Railways

Sr No	Detection Method	Requirements	Approximate Cost
1	Track Circuiting	Electricity	Approximately 3000 USD per unit of unit length for yard and 6000 USD for Block
		Display system	
		Integration with Signaling of Relay and solid-state types	
2	Axle Counter	Electricity	Approximately 2500 USD per unit of unit length for yard and 5000 USD for Block
		Display system	
		Integration with Signaling or Relay and solid-state types	

A simple track circuit Schematic diagram and Axle counter wheel sensor are shown in figure 2.

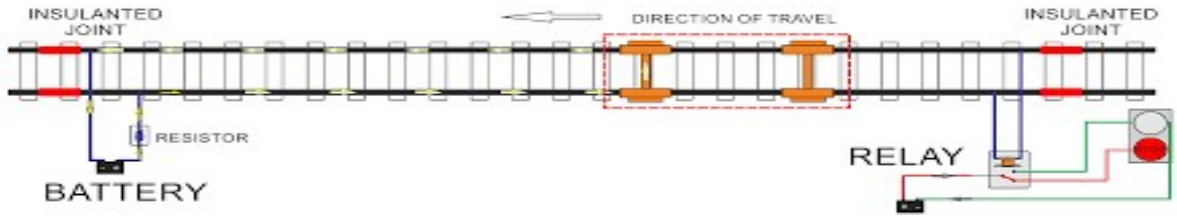

Figure 2: Track Circuit Schematic

Figure 3: Axle Counter which Counts number of wheels moving over it

In table 2, the entire existing systems and their relevant cost are tabulated. The above-mentioned systems are reliable, fail safe, state of the art, and compatible with modern signaling systems.

However expensive, not economically viable for the lines with less train density and beyond buying range of the Pakistan Railways.

Contrary to the above stated methods there are several other characteristics which can be manipulated to detect the trains with less complexity and less cost impact. In this paper two of such methods are proposed and discussed.

1.1 Problem Statement:

The applied and implemented solution for the detection of train are expensive and require huge allied works i.e., cable laying, power supply on longer distances and dependency over signal and interlocking system. Moreover, extensive operation and maintenance activities and supervision is also required. Over the railway track lengths where very few train are run, such expensive and complex systems can be desired but not feasible and economically viable. There is a dire need of safe, less complex and cheap solution to detect trains where not very advanced systems i.e., ARI, standard-III Mechanical interlocking, are available.

1.2 Literature Review:

In Pakistan Railways, in past not such any progress have been made which can be acknowledged in this regard. The existing systems which Pakistan railways use for train detection are Lock bar Arrangements for Switch and crossings, Treadles ahead of ASS and HS, Track Circuits for straight track and switch and crossings, Track Circuits for Block Sections, axle counters for Block Sections. Further to Control and Manipulate LX Pakistan Railway in joint venture with NESCOM implemented a level crossing control system in which trains are detected using Proximity Sensors.

In one study the researchers have proposed the use of RFID tag and detection to detect the train for Level Crossing system [1]. Same technique has been used by other researchers for detection purposes in their work [2], [3], [4], [5], [6]. Another study research has proposed another way for detection of trains using image processing. This technique further extends to speed estimation, detection of rail switch passages, adaptive blur removal approach for inspection, and detection of wear of rail guide [7], [8], [9], [10]. One study has proposed a complete train position system using RFID Technology which is in fact a very Novel Approach. This paper concentrates on examining and confirming the appropriateness of radio frequency identification (RFID) technology for aligning vehicles with switch and crossing (S&C) positions within the railway network [11].

In another study [12] researchers proposed method, which utilizes a DC power supply, has the capability of detecting cracks in railroad rails. This solution effectively reduces the risk of railroad track failure, which in turn prevents potential fatalities that may result from human error. Numerous moving and stationary items have been tracked and identified with the use of RFID technology. Enhancing large-scale transportation infrastructure's efficiency, timing, and dependability is one of the most difficult uses of RFID. This study identifies several problems such

as collisions and inadequate reading time and suggests many solutions for UHF-RFID enabled railway systems [13].

In [10] the writer discusses and proposes a way to not just detect but calculate the speed of the mobile unit, i.e. vehicle. The purpose of this work is to calculate the minimum vehicle speed required by traffic monitoring systems. These systems are extremely helpful for managing and monitoring a variety of traffic conditions, including safe transit, accident prevention, and traffic management. Now it is apparent that studies have explored various approaches to detect the Objects while developed their respective system, but there are challenges related to complexity, and cost that need to be addressed.

1.3 Purpose of the Study

The aim of the project is to offer an efficient train detection system that is cost-effective, low maintenance, human-intervention-free, and can be integrated with any gate control, signaling, interlocking, or warning system. The system makes use of image processing technology to detect the locomotive and break van of every approaching and departing train at the Advanced Starter Signal and Home Signal. This ensures that the train is detected at the outer signal and that its arrival and departure are recorded accurately. The data collected can also be used by level crossings to calculate the speed of the train and determine if a train is approaching. This information can then be used to adjust the gate's locking system.

2 METHODOLOGY

As described in table 1, Bogies, wagons and Locomotives can be detected with use of image processing models. The such detection is proposed to be used for train detection.

2.1 Proposed System Working

The camera sensors will be installed where the detection is required i.e., Outer Home Signal, Home Signal, Advanced Starter Signal and at Level Crossing or simply at platforms. Initially for the proof of concept a computer with Image Processing tools be fed with raw data from the camera sensor which from the segmentation, filtering, feature extraction, processes the data and give out the information in the required format for the interlocking which will be in very simple format either train is coming, or train is not coming, as shown in figure 4.

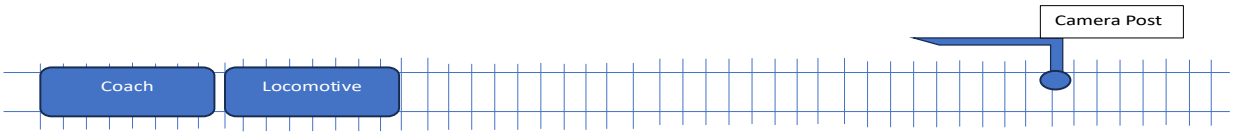

Figure 4: System of working mechanism

2.2 Applications of proposed system

Object detection technology is vital for safety and efficiency in railway control systems, including level crossings, computer-based interlocking, yard control, block control, and relay interlocking. In railways, object detection technology is essential for improving different control systems. To examine the specific railway control systems that use this technology, which is described in figure 5.

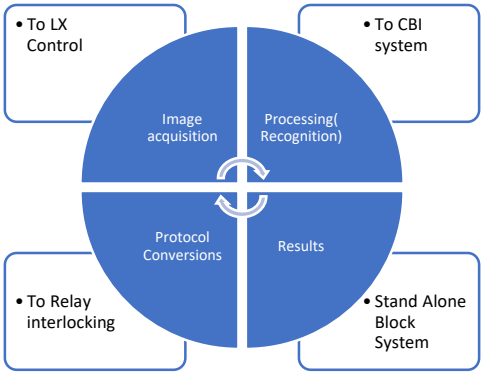

Figure.5 Potential application of object detection in railway industry

2.3 System Block Diagram

The acquired data from the image processing system will be in the form of detection of object i.e., train will not be in the compatible format to the interlocking system. The interlocking system either use relay-based interfaces or Modbus, Profibus or custom-built protocols based upon different products, hence protocol conversion will be required, as shown in figure 6.

Figure 6: Block Diagram from object detection to interlocking system

3 CONCLUSION

The development and installation of such a system will reduce the cost of train detection manifold as well as reduce the number of nodes for the maintenance. To sum it up, this research paper dives deep into how we detect trains on tracks. We compared the traditional methods we've been using with some new ideas involving Image Processing. The goal is to find a better way to know where a train is on the tracks without spending too much money. It's clear that the expensive systems we use now don't really work well in places where trains don't run too often. Something simpler and cheaper is needed that still does the job. That's where the idea of using cameras and Image Processing comes in. The cost for this is estimated to be around 1.2 million PKR, which is way more affordable compared to current methods. Moving forward, this new method will be tested against the old ones to see if it's really better. The hope is that this simpler way of detecting trains can be a stepping stone for even more improvements, like using advanced technology. The goal is to make train detection practical, efficient, and affordable for everyone involved.

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