Global Positioning System Based Automated Railway Level Crossing

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***Abstract*—Due to their ability to reduce unwanted accidents, automatic railway level crossings are gaining popularity in modern transportation systems. Many systems have been proposed and tested to achieve the desired automation, none of which have been considered a standard. Global positioning system is an effective and fast mode of communication and may be considered as an accurate tool to determine one's navigational information. The present work proposes an algorithm to automate the railway level crossings, which works based on global positioning system data. An experiment has been conducted to detect ones onboard location from a stationary point, with the help of Global Positioning System. The proposed system does not require the installation of track-side hardware and thus reduces maintenance cost by avoiding issues such as continuous monitoring and protection against vandalism.**

***Index Terms*—Automated Railway Level crossing, Global Positioning System, Cost Optimization.**

I. Introduction

Indian Railway is the largest and busiest transportation system in India. Every day the Indian Railway carries about 22 million passengers. Simultaneously, it has to face substantial challenges in its daily functioning, such as derailments, railway collision, level crossing accidents etc [1]. One of the major concerns is the accident befalling in railway level crossings. A railway level crossing is an intersection of road and railway track. Conventionally, human effort is deployed to ensure accident free journey of both railway and road transport. Lack of proper coordination may lead to major accidents, affecting transportation system. At the same time it also generates a high time delay to both the modes of transportation due to manual controlling of level crossings.

Indian Railway uses a system where all the level crossing gates are controlled manually by the gatekeepers. This may result in inadequate or erroneous information leading to some unwanted accidents. The rate of human error that could occur in these level crossings are high due to lack of actual knowledge, information and proper, timely co-ordination. The human errors such as delay in informing to the gatekeeper about the arrival of the train, delay in the gate operation by the gate keeper, obstacles stuck in the level cross, delay in opening and closing of level crossing gates may also result in some critical damage.

In recent times, attempts have been made towards implementation of Unmanned Level Crossing (ULC) [2] by the Indian railway transportation system. The ideology is based on some hardware components, where two blinkers and a siren have been used to alert people when the train is within one kilometer [3] radius of the level crossing. Such system uses some micro controller and other hardware which have been placed at a certain distance from the level crossing for observing an approaching train. The main problem regarding such systems is about vandalism to the installed hardware, which is also effecting railways economy.

The present work is an attempt towards design of a system for unmanned level crossing. It does not involve extra hardware installation, which reduces the risk of vandalism. This system also provides a better level of safety and security to both railway and roadway passengers. In this proposed method Global Positioning System (GPS) has been taken into consideration for detecting a railway vehicle approaching towards the level crossing within a short span of time. Based on this, it controls automatic opening and closing operation of level crossing gates. It also aims toward reduction of total time taken in gate operation at any level crossing and ensures the safety of the passengers at the level crossing when the train passes.

The organization of the work is as follows, after this brief introduction, the required related work for this topic is presented in Section II. This includes a brief discussion about Indian Railway level crossing operations, Advanced Train Safety System (ATSS) and Unmanned Level Crossing (ULC). The problem setup with an emphasis on the proposed algorithm is presented in Section III. The proposed algorithm along with an experimental result is described in Section IV. Section V concludes this study with some advantages of this proposed system and provides a direction towards future work.

II. Background Study

In India, level crossings have been controlled manually since tracks were laid on ground. This system involves a gatekeeper associated with every single level crossing, who actually controls the gate's operation. These gatekeepers are generally directed from a nearest cabin room over a telephonic conversation [4]. Such systems are prone to risk for heavily scheduled transportation systems. These systems can generate several kinds of human errors due to inadequate information within that stipulated time, resulting in unavoidable accidents.

Previous related works [3], [5]–[7] demonstrate the Advanced Train Safety System (ATSS). It has been defined that during the process of developing ATSS, a fault tolerance method has been applied for both the hardware and the software components. Automatic Level Crossing (ALC) systems have been successively implemented in Korea in the year 2000. It has reduced the rate of accidents at level crossings since then. In [7], the disadvantages of manually operated railway signals and railway warnings at level crossings are described in details. In [6], we find a detailed discussion about the railway auto control system using Open Services Gateway Initiative (OGSI) and Java Expert System Shell (JESS). As described in this paper, the state of a railway cross can been estimated by JESS methodology. The different ways by which a locomotive pilot can avoid accidental situations and the necessary measures to be taken in level crossings have also been discussed.

To improve the safety in level crossings, automatic alert systems from train to the people has been designed in [8], where the location Application Programming Interface (API) provided by telecommunication service provider, generates SMS warnings to road users. Such systems may definitely cause problems for large volume of traffic. In another work, the statistical information of the railway crossing properties, along with a variety of practical problems involving random process has been explored in [9]. Frequency Modulation communication systems have also been introduced for automatic gate controlling [10], where two IR transmitter and receivers with a sensor have been placed at a distance of $1km$ on both the sides of level crossing gate and the operation of the gate depends upon the activation of the sensors. A GPS receiver was designed and operated to monitor L-band amplitude scintillation and the ionospheric irregularities were monitored by [11]. Train anti-collision and level crossing protection systems with four different modules has been presented in [12]. Micro controller and IR sensor has been involved for automatic gate operation so that the manual errors can be reduced and a fast response can be obtained in [13]. A signal control system based on Internet protocol for railway controlling has been developed by East company in Japan [14]. A brief description on automatic railway barrier system in Indian Railway and its financial comparison with manual systems has been produced in [15].

Modern methods like Automatic level Crossing (ALC) or Unmanned Level Crossing (ULC) have been introduced to Indian railways where level crossings are controlled by micro controllers and sensors for detection of approaching trains to the level crossing. These system need few high priced sensors and hardware. Such systems may perform properly but it has some disadvantages like failure of system, breakage of hardware model and some vandalism issue [16]–[19]. At such point, the whole system will definitely fail and may or may not produce a correct estimation, leading to major accidents.

The present work is a proposed solution for ULC using a GPS system, which is a wireless radio navigation and positioning system that uses satellite data to identify the correct position, distance and velocity of a train or a body.

III. Problem Statement

Conventional railway level crossing control technique is completely dependent on railway signaling and manual effort. Manual control increases the time delay in level crossings and may sometimes may hamper the safety of the passengers. The current intelligent systems for ULC are based on some extra hardware installation and adaptation of new control systems with some modern methodologies. Such systems are essentially very costly and also invokes a risk of vandalism. Also, damage to such hardware may cause uncertain results and accidents thereafter. These systems are very expensive and may become a hindrance towards real time implementation.

IV. PROPOSED SOLUTION

GPS can be considered for detection of a railway vehicle approaching towards the level crossing within a short span of time. The proposed solution for ULC using GPS system where GPS tracking data is used to identify the exact position, distance and velocity of a running train and working of level crossings with this data, is described as follows.

A. Proposed System

The figure depicts the actual working cycle for ULC. The whole system consists of a locomotive, GPS, communication network, zonal cabin and all the listed level crossings which are in the range of that cabin. All these components are interlinked as shown in Figure 1.

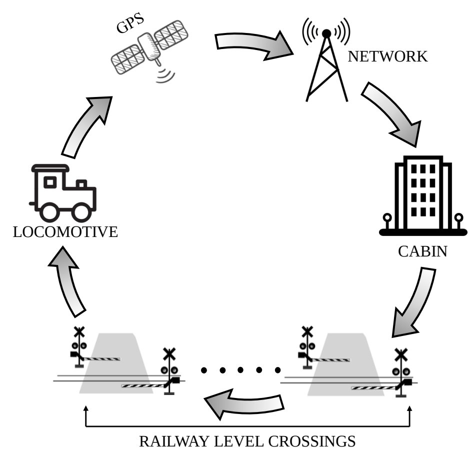

Fig. 1. The overall working cycle for Unmanned Level Crossing

The cycle describes a simple run on which the ULC will work. A locomotive has been considered running, in which a GPS module with a unique identification number, valid for only railway locomotives, has been placed. Also, this unique identification number is stored in the system to track the locomotive. Further, this tracking information is fetched by the zonal cabin with the help of a communication network where the actual system is running constantly. Discontinuity of network service may affect the proposed system badly. Such problem can be addressed by using stable internet frameworks such as GAGAN [20], [21].

The zonal map consists of a detailed information of each and every station, signal, and level crossings which have been stored inside the system. With such kind of communication, the zonal cabin is constantly tracking the locomotive and is able to independently fetch the required data itself and calculate the velocity, distance, and many other required parameters.

The speed of the locomotive can be calculated by using the GPS coordinates and time, where the two latitudinal/longitudinal positions can be converted into Universal Transverse Mercator (UTM) measurement and the difference between the two timestamps will calculate how long it took to get from Point A to Point B. This is only an estimate of the speed between the two points and it's accuracy will depend on various factors, including the distance and time elapsed between the two GPS measurements.

For ULC based solutions, tracking a train before $1km$ of level crossing has been considered a secured position. The algorithm running in the cabin, knows about the actual fixed position of railway level crossing and will check whether the distance between the train and the level crossing is equal to 2kms or not. Whenever such a condition occurs, the cabin will activate the upcoming level crossing, resulting in the closing of level crossing gate and will again open the gate after passing of the train from that particular level crossing when the locomotive is found to be 1km far from the gate. This system will work similarly with all the other level crossing placed within the range of a particular zonal cabin. As the train passes a particular zone, it will be now tracked by the new zonal cabin where the initial present location of the locomotive will be informed to the new zonal cabin by the former, through communication network.The new cabin will now start tracking the train from that location. The same process will be followed until the train reaches its destination.

As the locomotive covers a certain amount of distance and reaches the end of a zone. The original zonal cabin will transmit the last location of the locomotive to the new zonal cabin through network, where the system will now start tracking the locomotive from that location. Similarly the system works for the complete journey. Table I gives a comparative study with other prevalent systems implemented for ULC based solutions.

B. *Result and analysis*

Experiments have been conducted to detect the availability of a running train within $1km$ distance on railway track. For this purpose the algorithm implemented in a laptop with GPS interface was set up in Barrackpore railway station (Indian Railway Eastern division). The GPS location data is shared with the above mentioned setup by using Google API of a mobile phone on-board a running train. For proof of concept, Google API data of both the setup (both stationary and on-board) have been used to feed the latitudinal & longitudinal information in the presented algorithm. Further, the latitudinal & longitudinal data are pre-processed to convert to (UTM) data. These UTM locations are further fed to the algorithm in order to calculate the distance.

After calculating the distance between the stationary and on-board mobile point the algorithm raises an alarm when the calculated distance satisfies the distance constrains. This experiment has been conducted five times. Result of one typical experiment is presented in Figure 2. The figure depicts two final GPS locations of stationary and on-board mobile with a dotted connection within them reflecting the trains path. The distance calculated by the system is $1.0km$ as shown in map. In this proposed system, the distance has been calculated from two different UTM points which are converted from two proper GPS locations (stationary and on-board).

TABLE I
OTHER PROPOSED SOLUTIONS TOWARDS ULC

Serial No.	Hardwares Used	Merit	Demerit
1.	Arduino, sensors, server, internet, database, HD camera	Not dependent on a single hardware	Risk of server down or internet problem, Vandalism issue
2.	GSM-Modem, GPS, Alarm, ARM7TMD, Micro-controller	Quick data transfer, High instruction throughput	Risk of no GSM signal, No proper security of micro-controller
3.	Wheel detecting sensor, Vibration sensor, IR sensor, LDR, Arduino UNO	Proper scheduled work of hardware, Quick response time, Vandalism issue	IRsensor can detect any obstacle, noise feeded vibration results
4.	LCD screen, Zigbee, Motor driver, APR9600 speaker driver	Organized time fitted to control Level crossing	Zigbee systems are not secured, Limited coverage of communication.

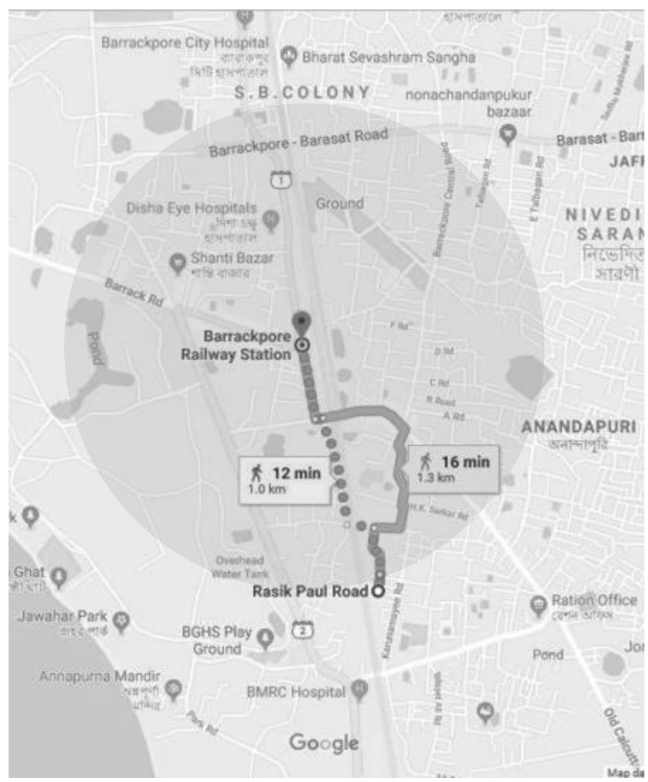

Fig. 2. Train Detection withing 1km of radius using GPS

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$d = \sqrt{(640773.19 - 640945.50)^2 + (2517692.89 - 2516707.56)^2}$$

$$d = 1000.28\ m$$

The distance calculated between these two points is $1000.28m$. It can be seen from the Figure 2 that the proposed navigation performs at par with oher systems.

TABLE II
RECORDED EXPERIMENT OBSERVATIONS WITH GPS

No of Run	Staionary point (Latitude & Longitude)	UTM(East & North)	Distance from UTM
1.	22.751421 , 88.372760	640948.35 , 2516655.66	1051.92 m
2.	22.751678 , 88.372744	640946.44 , 2516684.10	1023.56 m
3.	22.751257 , 88.372798	640948.35 , 2516655.66	1000.28 m
4.	22.751889 , 88.372713	640943.04 , 2516707.43	1000.98 m
5.	22.751257 , 88.372798	640952042 , 2516637.54	1070.46 m
		Average distance (m) :	**1029.45 m**

The information presented in Table II have been gathered from the real experiments conducted for five times. For this experiment, one fixed point has been chosen (Barrackpore Railway Station) with its GPS coordinates as $22.760803N$, $88.371148E$ and their UTM coordinates are found to be 640773.19 E , $2517692.89N$. In every run, GPS location of both stationary and on-board mobile has been recorded.

$$d = \sqrt{(E_2 - E_1)^2 + (N_2 - N_1)^2}$$

The 2D co-ordinate system has been used to calculate the distance within two UTM points. The average calculated distance is found to be 1029.45m which is very close enough to the distance provided by Google API in the map.

V. Concluding Remarks

An algorithm for GPS based ULC system pertinent to Indian Railway has been proposed. The proposed system consists of a GPS through which the arrival or departure of a railway vehicle can be detected for a particular level crossing. The effectiveness of this proposed system has been explored by calculating the distance from a stationary point of a running train. GPS data have been used to validate the correctness of the proposed approach. The system is characterized by providing a safe guard against vandalism as it does not require hardware installation in open space. The proposed system may be considered as a cost effective support to the existing technology as well as one feasible solution for ULC problem.

Real time experiments by implementing such systems need to be carried out and may need few modifications based on the nature of the level crossings and increase the adaptability in the Indian scenario. These issues are crucial and call for some further research work in this field.

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