Intelligent Collision Detection and Avoidance in Railways using GPS/RF Module

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Abstract - Railways are an important mode of transport because it can carry large number of people and goods at the same time, so it is important to protect the people’s life and property. There are many collision accidents between trains, because of irresponsibility of drivers and signaling problems. Several techniques have developed in order to avoid such danger loss of life and property. In this paper, we have proposed an approach using GPS and RF module for detecting and avoiding train collisions. The GPS module identifies the location, speed, and direction of the trains with highest accuracy. This information transfers to the train microcontroller in the same vicinity via RF module. The availability of the information allows the train microcontroller type PIC16F877 to take accurate decision as for train location. This system warns the driver both visually and by giving an alert sound, to allow avoiding the collision between trains when they are separated by one kilo. We used a vibration sensor for sensing the train on the track. The prototype was designed using microcontroller and tested successfully through RF communication.

Index Terms - Wireless LAN, Collision Detection, Micro Controller, Train Anti-Collision System.

I. INTRODUCTION

Railways are a mode of transport essential to the daily life of people. It can carry large numbers of people and goods speedily at the same time. It is cheap and affordable mean of transportation for millions of passengers. According to COMESA Infrastructure Statistics, it carried more than 292 million people and 5.8 million tons of goods in year 2010 as [1]. According to COMESA Infrastructure Statistics, the recorded drop in the number of passengers transported is due to lack of safety, as many accidents occur. Over the past ten years, more than one hundred people were killed and another about four hundred were injured due to railway collisions as [2]-[3].

Communication is a key issue in traffic management and tracking and railroad traffic control is not an exception. The human factor has proven to be the direct cause of these several train collisions as [4]. The driver does not know anything happening around. He does not have any information about other trains. He just sees the signal aspect and follows it. The signal aspect depends upon the ASM (Assistant Station Manager), so if the ASM gives wrong signals and gives wrong route, accidents will occur. Whole working is ASM dominant; therefore, the drivers cannot take any decisions. Rail accidents are inevitable where communication is inefficient, hence the need to device systems which will enable trains to communicate automatically. With the aim of reducing injury and accident severity, pre-crash sensing is becoming an active research area.

According to an aspect of the present situation, this paper describes an intelligent detect and avoidance collision system that can be used to avoid collision between trains. The proposed system is based on direct train-to-train communication. The system allows trains’ autonomous detection to imminent collisions. Designed as a safety overlay system, it shall warn train drivers in such situations. This approach is based on GPS and RF module and receivers. The GPS receiver is capable of identifying the longitudinal and latitudinal position and the speed of the specific train by receiving information from satellite. The time delay of GPS is very small, and the accuracy of GPS is from 10 to15 m which is 0.3 to 0.5 % from the 3 km we calculate so we can neglect this value.

The Radio Frequency (RF) module is used in this system to allow exchanging the train’s information between trains in the same vicinity.

The rest of this paper is organized as follows: section II discusses the related works, section III describes the system overview, section IV describes the proposed system structure, section V explains the scenarios of collision, section VI explains working flow, section VII indicates the results, and finally conclusion is discussed in section VIII.

II. RELATED WORKS

Many methods have been developed and used for avoiding collision and for getting proper communication. Intelligent Collision Avoidance System ICAS as [5] is based on Radio Frequency RF transmitters and receivers to sense the direction and the position of the trains. RF transmitters determine the track IDs and the position of trains in main tracks or sub tracks. They put vibration sensor at starting and ending of sub tracks. When the trains are on the same track and are separated by three-kilo meters, the system
warns the driver both visually and gives alert sound for avoiding frontal collisions. The disadvantages of this system that eliminates the potential for collisions includes; the position of trains are not accurate and the speed is unknown.

Another method using powerful combination of mobile computing, Global System for Mobile Communication (GSM), Global Positioning System (GPS), Geographical Information System (GIS) technologies and software for improving railway security and safety and predict the dynamics of trains collisions as [6]-[7]-[8]. The in-built GPS module identifies the train location and speed with a highest accuracy and transfers the information via GSM to the central system to identify the possible safety issues. Location data processed to provide visual positioning using maps granting a wholesome view on train location. Positioning data along with train speed helps the administration to identify the possible safety issues and react to them effectively using the communication methods provided by the system. This system reduces waiting time, provide automatic information of train, knowing about the train arrival time & location. Using a SMS people can find the location & time of arrival but it needs infrastructure.

Other system uses WIMAX for detecting and avoidance collisions as [9]. In this system using latest 4G technology WiMAX (Worldwide Interoperability for Microwave Access) i.e. IEEE802.16e standards for preventing train accidents. The approach helps the train to know the location of its own with the help of fixed WiMAX base stations whose positions are known. The approach does not require extra GPS service for calculating location, like the one existing railway system uses. The WiMAX base station and the train (mobile stations) contribute in sending the information to the trains whenever a train comes in its vicinity and range. The trains will be equipped with WiMAX enabled laptops/tablets for communicating with others. The speed, location and distance of other trains are known in advance to increase awareness and safety. The distance calculated between the train and the base station is based on angle of arrival (AOA) and received signal strength (RSS). Using this information, the trains will be able to take possible precautions to avoid collision. The technique will be more efficient and beneficial for avoiding situations like collision and catastrophic hazards. The advantages of this system includes, not requiring GPS receiver and no need for infrastructure. The disadvantage is being expensive.

### III. DESIGN PATTERN

The Intelligent Collision Detection and Avoidance system is based on integration of GPS and RF model as shown in FIG. 1. This system consists of three sections: 1) base station: which identify the track ID, 2) train unit: where a GPS identifies the train location, speed and direction and where controller takes the accurate decision to avoid collisions, 3) sub track unit: which detect the train location if it enters or leaves the sub tracks. The train has a controller unit that contains several parts; like transmitter which transmits the information about train that can be identified by GPS and the data about the track that identified by the transmitter at the base station. This information transmitted through Radio Frequency RF transmitter and received by RF receiver. Then the receiver sends this information to microcontroller where the controlling procedure is processed. The microcontroller processes the data and takes accurate decision to avoid collisions. The system also consists of sub track block for detecting the train position whether it is entering the sub track or leaving the sub track by using vibration sensor under the track, which senses the train moving.

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**FIG. 1. TOP VIEW OF THE INTELLIGENT AVOIDANCE COLLISION SYSTEM**

### IV. PROPOSED SYSTEM STRUCTURE

#### A. Base Station Unit

Two RF transmitters (1 in FIG. 1) mounted at base stations. One is at the beginning of the track and the other is at the end of the track. Each transmitter has a particular code signal that identifies the track IDs. When the train starts to move, the transmitter transmits the code of the track to the train to avoid the collision.

#### B. Train Controller Unit

Every train has a train controller unit that processes the information to take the correct decision to avoid the collision. The system consists of GPS, Transmitter, Receiver, Microcontroller, LCD and Alarm. The microcontroller unit in vehicle section module sends alarm sound and message for different events to the driver as:
• Green LED and GO message: when the trains move at different tracks and no collision occurs,
• Red LED and STOP message: when the trains move in the same track and different direction and
• Red LED and STOP OR REDUCE THE SPEED message: when the trains move in the same track and the same direction.

C. Sub Track Unit

Sub track is the path that branches from main track. Both starting and ending of all the sub tracks are equipped with vibration sensors and a low power transmitter. The transmitters T_{x1}, T_{x2} used to inform that the train entering or leaving from the sub track, respectively. The block diagram of the sensing unit shows as in FIG. 3. The sensors consist of crystal that is mounted between two iron pieces and placed under the track. The force exerted on the track by the train makes the crystal to vibrate and oscillate. These oscillations amplified and converted to digital format and gives to the microcontroller. The sensor will produce signals only when trains are on the specified track where it placed. The sensor will not produce signal when there is a train on nearby track.

When a train is moving on the track, the sensor produces a signal due to vibration of the track. We have selected vibration sensors because it will produce signals only when train is on the specified track where it placed. The sensor will not produce signal when there is a train on nearby track. It is a generalized system easily accommodated in any train. The output level of vibration sensor is very low, in terms of millivolts (150 mv). The output is amplified and converted into digital signal using ADC 0808 and given to micro controller.

V. COLLISION SCENARIOS

In railroad transport, well-defined collision scenarios will be distinguished in different modes of operation. Table1 illustrated scenarios of collisions and the expected output to the drivers.

• Scenario 1

When two trains are at different tracks as in FIG. 4 and each track has a particular code, so each train has a different track ID. The microcontroller compares between tracks IDs of the trains that train receivers receives, when track IDs are different, so the output light will still be green that means, safe case and no collision danger.
Scenario 2

When two trains are on the same track and in the same direction as in FIG. 5, the memory of the trains has the same track ID. The microcontroller calculates the distance between them in addition to the length of the train, if the distance is less than 2 km and the direction is the same then alert the drivers by giving alert sound and the red output light on, and by message to stop or reduce the speed of the second train.

Scenario 3

When two trains are on the same track and in different directions as in FIG. 6, the memory of the trains has the same track ID. The microcontroller calculates the distance between them, if the distance is less than 2 km and the direction is different, alerts the drivers by giving alert sound and the red output light on, and by message to stop the trains to avoid the collision between them.

Scenario 4

When two trains move above another train as in FIG. 7 each track has different track ID, so the microcontroller found it safe case and does nothing.

Scenario 5

When the train switches from the main track to the sub track: Starting and ending of each sub track equipped with sub track module to identify the location of the train when entering or leaving the sub track. Each sub track has a particular code. When the train leaves the main track and enters to sub track, the train receives the code of the sub track and changes its track ID and when it leaves the sub track, it receives the same track ID again then automatically changes its track ID again to main track ID. When a train is moving on the sub track, the sensor produces a signal due to vibration of the sub track. The transmitter $T_{s1}$ that is present in the sub track transmits with the signal SUB111. The $R_T$ receive the signal by and pass it to the controller. The controller will store it and transmit through $T_T$ indicating that the train is in sub track. At the end of sub track, receiver $R_T$ receives SUB111 again from transmitter $T_{s2}$ indicating the end of sub track and hence the controller automatically generates the signal LIN111.

Scenario 6

If the train enters from main track to other main track directly as in FIG. 8 the vibration sensor placed a distance of 1km from the intersection before the train enters the other main track, and transmitter $T_x$ transmits signal code LIN111 which is the code of the main track.

<table>
<thead>
<tr>
<th>COMBINATION OF CASE STUDY</th>
<th>EXPECTED O/P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>audio</td>
</tr>
<tr>
<td></td>
<td>writing</td>
</tr>
<tr>
<td>1. Two trains at different tracks</td>
<td>3 beep</td>
</tr>
<tr>
<td>COMMENT: Each train has different track ID, so there is no collision occurs. This case was implemented.</td>
<td></td>
</tr>
<tr>
<td>2. Two trains at the same track &amp; same direction</td>
<td>5 beep</td>
</tr>
<tr>
<td>COMMENT: Each train has the same track ID, the microcontroller compare between the direction and depending on the speed, alerts the driver to reduce or stop the second train. This case was implemented.</td>
<td></td>
</tr>
<tr>
<td>3. Two trains at the same track &amp; different directions</td>
<td>5 beep</td>
</tr>
<tr>
<td>COMMENT: Each train has the same track ID, the microcontroller compares between the directions then alerts the drivers to stop the trains. This case was implemented.</td>
<td></td>
</tr>
<tr>
<td>4. Train underground and the other above it</td>
<td>3 beep</td>
</tr>
<tr>
<td>COMMENT: Each train has different track ID, so there is no collision occurs. This case was implemented.</td>
<td></td>
</tr>
<tr>
<td>5. When the train enters to sub track</td>
<td>3 beep</td>
</tr>
<tr>
<td>COMMENT: Just the train moves on vibration sensor a TrackID will change. Green light ON if the two trains in different tracks and red light ON if the two trains in the same sub track.</td>
<td></td>
</tr>
<tr>
<td>6. two trains will Converge at intersection point</td>
<td>5 beep</td>
</tr>
<tr>
<td>COMMENT: Put vibration unit just 1km before intersection point to change the trackID of the train. The trains have the same trackID and depending on the speed, alert the driver to reduce or stop the second train.</td>
<td></td>
</tr>
</tbody>
</table>
VI. WORKING FLOW CHART

In order to detect and avoid collisions between trains, train locations must be identified. The Follow pattern algorithm 1 Appendix A shows the steps for locating the trains in this system. The input to the system is a longitude and latitude from GPS receiver and track ID from RF transmitter that is at the base station. The first task processing the data from GPS by microcontroller then stores this information in the memory. When the microcontroller receives information about other trains, then it compare between track IDs of the two trains. When the track IDs are the same, then it calculates the distance between them and compare between the directions of the trains to take accurate and appropriate decision for avoiding collision.

Algorithm 1 Flow chart of the decision-making system

Inputs: GA GPS Information , IDA Track ID , 
GB GPS Information , IDb Track ID
Outputs: L Light , Str Messages , B Beep

1. IDA = GetMyTrack ID()
2. GA = GetMyGPSINformation()
3. WHILE LOOP
4. IDB = GetOtherTrackID()
5. GB = GetOtherGPSINformation()
6. Distance = CalcDistance(GA , GB)
7. IF IDB == IDA THEN
8. IF Distance < 1km THEN
9. Str = “Stop”
10. Return(5B , Red L , Str)
11. ELSE
12. Str= “Reduce speed or Stop”
13. Return(5B , Red L , Str)
14. END IF
15. ELSE
16. Str = “Go”
17. Return(0B , Green L , Str)
18. END IF
19. ELSE
20. Str = “Go”
21. Return(0B , Green L , Str)
22. END IF
23. END LOOP
24. END LOOP

VII. RESULTS

Our system implemented and tested as shown in the following figures. Here the variables Lat, Long and H indicate latitude, longitude and height of the train respectively. The direction 0 → indicates that a train moves from base station A to base station B for example and the direction 1← means that the train moves from base station B to base station A as in FIG. 9.

FIG. 10 shows the result for the scenario 1 of FIG. 4. According to FIG. 10, the track ID is different so appear the GO message to driver. The result for the scenario 2, shown in FIG. 11, so alert message appear to the driver of the second train to stop or reduce the speed and GO message to the first train. FIG. 12, show the scenario 3 and the trains move in different direction. So alert the drivers to stop the train by giving STOP messages. The scenario 4 tested as in FIG. 13 that shows that the track IDs of the trains are different so it is safe case and no collision will occur and GO message appear to the drivers. When the train enter to sub track as illustrated in scenario 5, here we tested when one train still in the main track and the other one enter to sub track as in FIG 14.

The flank collision scenario of FIG. 8 tested and indicated that the two trains have the same track ID and same direction.
VIII. CONCLUSION

In this research, a scalable rule-based system for detecting and avoiding collisions between trains has been designed and developed based on microcontroller. A GPS/RF module for locating trains is proposed for detecting and preventing collisions. The system demonstrates different expected scenarios for single and multiple tracks. The system has a graphical user interface and information displayed in a way that is familiar for administrators, and drivers. This system implementation and tests are successful. The software designed using PICBASIC PRO language, and completed using a Java program. The allotted code of a particular transmitter can be re-used. A prototype designed to test the feasibility of the collisions prevention. Results show that this approach is appropriate to validate the collisions prevention and increases the reliability of the system. Moreover, simulations show the feasibility of the proposed solutions.

The goal of this work is to design and implement a cost effective and intelligent system to avoid collisions. We believe that the system is more suitable for the developing countries. Enriching the system by adding more knowledge rules is a continuous process.

REFERENCES

Appendix A

Flow chart of the decision-making system