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Real-Time Intelligent Traffic Light Monitoring and Control System to Predict Traffic Congestion Using Data Mining and WSN

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Abstract*— Traffic monitoring and control are becoming more and more important as number of vehicles and traffic jams grow. Strategically placed video cameras are predominantly used to perform this task by visual means. To improve traffic monitoring and control this paper presents Real-time Intelligent traffic light monitoring and control automated system, to predict traffic congestion using Iterative Dichotomiser 3 (ID3) data mining algorithm and Wireless Sensor Network (WSN). At a junction, infrared sensor is used to count the number of vehicles on each road and send the report to Traffic Monitoring and Control (TMCM) for traffic estimation[1]. Along with infrared sensors, this system consists of light, temperature and gas sensors to measure day-night, temperature and pollution at the junction. Traffic and climatic data obtained from these sensors are aggregated in TMCM to form data logs stored in database, which is further used to extract traffic information as per system requirement. TMCM consist of micro controller (AVR ATmega32), Bluetooth (HC-05) and an android device for connecting server to different sensors like IR sensor, temperature sensor(LM35), light sensor and gas sensor with the help of MAX-232 and ADC. Proposed system not only measures the traffic flow and different climatic scenarios through wireless sensor nodes but also predicts the possibility of traffic congestion for relevant junction by using CSE5230 ID3 Data mining algorithm on collected database. Using historically collected data from database system intelligently decides the delay timer of Red-Green-Orange traffic signal light. This delay timer is automatically set based on the flow of traffic on each road of associated junction and data logs maintained in database. Traffic congestion information and climatic scenario are employed for early warning with the use of server to android-based mobile phones or smart phones connected via a web service.

Keywords—ADC; AVR ATmega32; Data mining; HC-05; LM35; MAX 232; Wireless Sensor Networkt (WSN); Analog To Digital Convertor (ADC); Traffic Monitoring and Control Module (TMCM); Interative Dichotomiser3 (ID3).

I. INTRODUCTION

In recent decades travel demand in urban area has rapidly increased along with the growth of economic activity and population, however, infrastructure transportation has slowly expanded due to limited space available. Soothing the traffic congestion in urban road network has been a crucial issue for both the research and practical operation. A beneficial and reasonable solution may not obtain always by supplying new infrastructure. Hence, use of existing infrastructure via intelligent or smart traffic management seems to be more feasible and calls for implementation and development of improved traffic signal control techniques and method.

A State of severe congestion that brings traffics in the network to standstill is Gridlock. Such state arises when local queue spills back, there by restricting traffic movement in all directions. In any urban transportation network the activation and evolution of urban gridlock is impacted significantly by traffic signal setting.

Transportation of goods, labor, industrial products and machinery are the keys factors, which influence the industrial and environmental development of any country. Traffic congestion and mismanagement will results in long waiting times, loss of fuel and money. It is therefore necessary to have a fast economic and efficient traffic control system for national development.

The monitoring and control of city traffic is becoming a major problem in many countries. Traffic monitoring authority has to find new methods of overcoming problems that arise due to ever-increasing number of vehicles on road. Till now the measures taken are development of new roads and flyovers in the middle of the city; buildings of several rings such as inner ring road; middle ring road and outer ring road; introducing monorails; restricting of large vehicle in city during peak hours and also development of sophisticated traffic monitoring and control system .

One way to improve traffic flow scenario of current transportation system is to apply automation and intelligent control methods to roadside infrastructure and vehicles.

A. Technical challenges:

We face some Technical challenges in trying to build our project that are mentioned below.

a) Android Bluetooth communication with hardware:

Connecting the Android mobile phone with our hardware we face some compatibility issues.

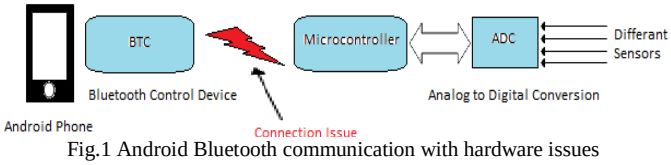

Fig.1 Android Bluetooth communication with hardware issues

b) Client and Base station communication with GPRS:

Connecting the Android mobile phone to GPRS may cause issues, like Android phone may not connect to the wireless router.

Fig.2 Client and Base station communication with GPRS issues.

II. MOTIVATION

One of the sever problem of today's society is on road traffic management. To reduce waiting and travelling times, save money and fuel an intelligent management technique is required. A large number of methods and approaches have been suggested in the literature in order to allocate the problem. In this section the various solution to the traffic control problem suggested in literature are present.

International workshop on "Agents in Traffic and Transportation" held at the 13th international conference on autonomous agents and multi systems (AAMAS), Paris France on 5-6 May 2014 in this workshop the topic of world-wide user friendly and effective transportation system was raised; this workshop emphasized on application of multistage technology in traffic transportation and logistics. It also expressed the importance of distributed decision making in traffic and intelligent monitoring of transportation system using agents. The purpose of this workshop was to bring the researchers and practitioners together in order to set up visions on how agent technology can be and is used for today's isolated IT-tools to model, simulate, and manage large-scale complex transportation systems.

III. LITERATURE SURVEY

Zahra zamani,Mohammad Hossein Saraee ,Mohmmad paurmand[1] presented the "Application of Data Mining in Traffic management : case of city of Isfahan which describes the work in use tagging the application of data mining tools. In this, case study was conducted to illustrate the use of hierarchical cluster analysis. Using evolution a Time of Day signal control system was designed. This system automatically identifies time of day(TOD) intervals using historically collected data.

A system deployed in Isfahan consist of sensors used for determining the volume of traffic. Each entry in junction had a sensor capable of counting the number of entry vehicles. The data collected was then used to deicide the time of the day by creating clusters with the help of Clementine software. It clustered holidays and weekdays separately from other days and further divided days into a cluster 4 cluster for holidays; 5 cluster for Business days and weekends. Tables for Time of Day intervals based on the gained cluster were then prepared for signal plan development.

After studying Application of data mining in Traffic management: case of Isfahan[1] one comes to know that, this system retrieves historically detector data and clusters the data over 24 hours time period. Then generate daily Time Of Day interval and timing plans based on historical data trends but is not able to control real time traffic flow and cannot provide or measure the different environmental condition.

Chunga yang,Yang cao,Zaiging Nie,Jie Zhou and Ji-Rong wen[2] presented "Design of Intelligent Traffic Light Controller using Embedded system". They had proposed a system, which makes use of Sensor Network along with Embedded Technology to intelligently deicide the timing of Red, Green light at each crossing of road based on the total traffic on all adjacent road. Users those who wish to obtain the latest position of traffic congested roads are provided with GSM cell phone interface which helps the car drivers to select an alternative route.

After studying Design of "Intelligent Traffic Light Controller using Embedded System". One come to know that this system controls real time traffic by taking into consideration the length of vehicle on each road. Thus in turn generating outputs signal for Red, Orange and Green Traffic light to monitor their timing but this system makes use of GSM system interface to provide information about traffic congestion which requires pre registration hence it's not so user friendly. This system does not provide information of climatic condition and about the Time Of Day i.e. day or night etc.

Imane L'hadi,marwa Rifai,Yssine Salih Alj[3] investigated energy by representing "An energy-efficient WSN based Traffic Safety System". They made efficient use of solar light pads that were deployed in dangerous portion of highways. They had arranged the poles in groups such that each group was equipped with a sensor and an actuator for vehicle detection (sensors) and for switching on and off the light-emitting diodes of group poles(actuators). In this communication between the system component was done through Zigbee Network which were relayed by the use of repeaters.

After studying "An Energy –Efficient WSN based Traffic Safety System" we understand how accidents can be reduced by providing proper lighting in dangerous portion of highways also the idea of efficiently using Solar Panel can be utilized with Embedded System.

Anand Gupta ,Sajal Choudhary,Shachi Paul[4] suggested "DTC:A frame work to detect Traffic congestion by mining versatile GPS data" system which utilizes the available GPS data for mining. The mining of this data is likely to help in detection of the location, which face frequent traffic congestion. All kind of GPS enabled devices like Mobile, Tablet and different vehicle has access to the data thus informing future traffic congestion, which help user to decide whether to opt for route.

After studying "DTC: A frame work to detect traffic congestion by mining versatile GPS data" system we come to know that such system does not gives accurate result because of its inability to distinguish between jams and random short –term stoppages. The author proposed clustering available as one of the solution, this system is only capable of detecting traffic congestion. It is not able to control real time traffic nor gives any information about climatic condition and Time of Day.

Kitae Jang ,Hgugjoo Kim and In Gwan Jang [5] defined Traffic signal monitoring and control by detecting grid lock situation. They proposed "Traffic Signal Optimization for Oversaturated Urban Networks Queue Growth Equalization" systems that makes use of signals optimization algorithm

aiming equalization of queue growth rates across links in oversaturated Urban road ways network .This algorithm was capable of delaying queue by simply distinguishing queue over those links rarely used. This system is capable of avoidin traffic congestion but not able to control real time traffic and also does not provide relevant information about current climatic scenario.

IV. NEED

There is a strong need for the implementation of a traffic light signal monitoring and control system globally.Very few traffic light controlling systems are capable of managing heavy traffic jam. They are not able to provide significant early warning against these time wasting congestions. Presently typical conventional traffic light controllers face various problems as mentioned below.

A. HEAVY TRAFFIC JAMS

Heavy traffic congestion has substantially increased in major cities with increasing number of vehicles on road. This usually happens at the main junctions commonly in the peak hours such as morning, before office hours and in the evening, after office hours. Increased time wasting of the people on the road is the main effect of this matter. The solution of this problem is by developing the program that is capable of detecting traffic scenario in real time and provides different setting delays. The junctions that have high volume of traffic should be setting longer delay than the delay for the junction that has low volume of traffic.

B. NO TRAFFIC, BUT STILL NEED TO WAIT.

People have to wait at certain junctions sometimes even if there is no traffic because the traffic light remains red for the present time delay, the road users should wait until the light turn green. They have to pay fine if they run the red light. The solution to this problem is by developing a system, which detects traffic flow on each road and set timing of signal accordingly. Moreover, synchronization of traffic signal in adjacent junction is also necessary.

C. EMERGENCY CAR STUCK IN TRAFFIC JAMS

Usually, an emergency vehicle such as ambulance, fire brigade and police will be stuck especially at the traffic light junction, during traffic jam. This is because the road users are waiting for the traffic light to turn green. It can cause the emergency case become complicated and may endanger life, so this is a critical issue.

D. LACK OF TRAFFIC INFORMATION TO USERS

Present traffic system fail to provide traffic information including congested road and alternate route available in the case of congestion.

In the proposed intelligent traffic light controller, all these limitations of existing controller are totally eliminated. The proposed project of “Real-time Intelligent Traffic light Monitoring and controlled system to predict traffic congestion using Data-mining and WSN” uses combined efforts of embedded systems and wireless sensors (micro-controller AT Mega) and has advantage of efficient control, monitoring via various sensors and an android user Interference. The fixed timer delay traffic light problem is eliminated in the proposed system. The main objective of this project is to design a program and implement hardware of intelligent traffic light system suitable for real life implementation. This project also aims to minimize the delay or waiting time at the road by designing a system that provides safe and efficient traffic flow and guides the right way[2]. By increasing the green signal delay time on busy road and decreasing the red signal delay time on non-busy road, one can reduce traffic jams. System can also provide the information about congestion on road or possible alternate routes to drivers on demand of his/her android device. To measure the traffic flow IR (Infrared) sensors are used. In short, this project is real-time, android base intelligent traffic light controller.

V. PROPOSED WORK

After studying literature survey and understanding the need globally, these papers are modified and a novel technique is built that gives best result like predicting the traffic flow on each road of the junction and setting the delay for red light more for the road with heavy traffic flow. System will provide notifications of congestion on heavy traffic flow to the drivers via their android device on demand. This may help the drivers to make decisions on whether to opt that route or not.

The Architectural diagram helps to understand proposed system in a better way. It consists of three modules all together these three modules communicate via wifi network with each other and form a system. First module consists of PC base station where all the data obtain from the system location is stored in data logs forming database. These data logs are then utilized to control the delay timing of traffic signal light.

Second module consist of the entire hardware made up of microcontroller, sensors capturing on field data in real time, Android devices included in this module to communicate with the hardware via Bluetooth and upload data on the server. This device uses android base application, which not restricted to any compatibility clauses. This module is actual Traffic Controlling and Monitoring Module (TMCM).

Third module is the user end, which includes android application installed on any android devices. This extracts the data from the server and displays it for use. Drivers make the use of this information and can opt for relevant route using their intelligence.

A. Architecture diagram:

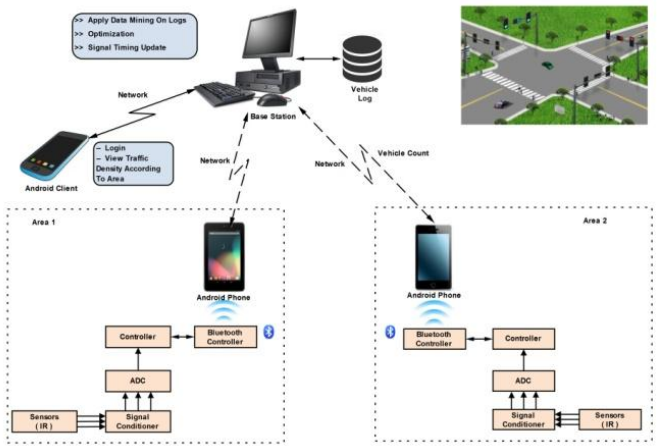

Fig.3 Architectural framework of Proposed System.

The proposed operation of the Real-time Intelligent Traffic Light Controller can be understood better with the help of following:-

First, all sensors sense various parameters and send it to ADC for analog to digital conversion. After signal conditioning these digital signals are forwarded to micro controllers, then micro controller have task to convert this digital data into user define format and send this data to server with the help of Bluetooth, Android Device and Rs-232. Every collected value or data logs are stored in database; applying the data mining on database, system provides the future prediction values.

Data mining works as a decision identifier or decision tree constructor. C0E5230 ID3 decision tree Algorithm constructs a decision tree using the concept of Information Gain. Further this decision tree is use to make a decision about new data. This predicted value is then used to estimate delay timer of red, green and orange light. All this operation is performed by TMCM, which not only stores the data; maintain logs in database but also provides smooth system user interface and communicated with user's android device whenever demanded.

B. Algorithm

ID3 data mining algorithm is applied on database to predict the delay time of traffic signal light. ID3 is a decision tree algorithm, which approximates discrete-valued target function to create predictive analysis environment. Its purpose is to manipulate vast amount of data and transfer it into information that can be used to make a decision. ID3 is selected as it creates simple and efficient tree with the smallest depth. Comparing to Huffman Encoding where there is just a left right node, the ID3 decision tree can have multiple children and siblings.

The ID3 decision makes use of two concepts while creating a tree from top-down. The nodes to be created and then the attributes to split on can be determined using these. The two important concepts are as follow:

a. Entropy

Entropy is the measurement of uncertainty where the higher the entropy, then the higher the uncertainty. With decision tree, this measurement is used to determine how informative a node is.

$$E(S) = -\sum_{j=1}^{n} f_s\ (j) log_2\ f_s\ (j)$$

where:

- E(S) is the information entropy of the set S
- n is the number of different values of the attribute in S
- $f_s(j)$ is the frequency (proportion) of the value j in set S
- log_2 is the binary logarithm.

b. Information Gain

Information gain uses the entropy in order to determine what attribute is best used to create a split with. By calculating Gain the improved entropy can be determined hence using particular attribute. So, the column with higher Gain will be used as the node of decision tree.

$$G(S,A) = E(S) = -\sum_{i=1}^{m} f_s\ (A_i) E(S_{A_i})$$

where:

- G(S,A)is the gain of the set S after a split over the A attribute
- E(S) is the information entropy of the set S
- m is the number of different values of the attribute A in S
- $f_s\ (A_i)$ is the frequency (proportion) of the items possessing (A_i) as a value for A in S
- A_i is the i^{th} possible value of A
- S_{Ai} is a subset of S containing all items where the value of A is A_i.

This project has three categorical attributes outlook, traffic flow on a road, and traffic flow for a junction. Designed system is intelligent to decide whether to make the signal light glow green and smartly decide the delay time for red, green and orange signal light to glow using data logs stored in database. If vehicle count for a particular road is zero the light may not switch to green. The system utilizes the data available in data logs and predicts the delay for which the traffic signal light remains red/orange or green depending on the real time traffic flow. A decision tree consists of nodes and arcs, which connect to nodes. To make a decision one starts at the root node, and ask question to determine which arc to follow, until one reaches a leaf node and the decision is made. The figure 4 shows basic structure of decision tree.

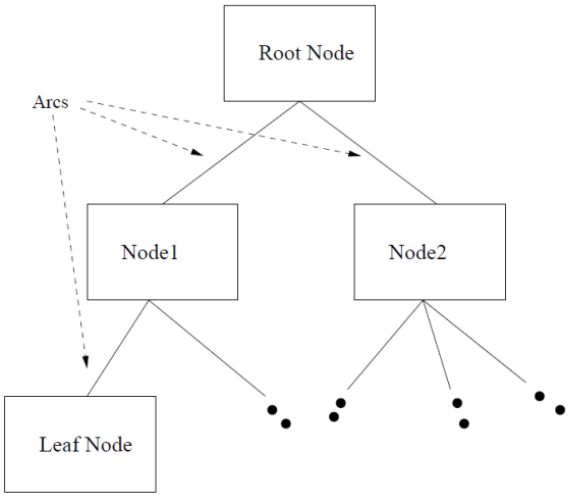

Fig.4 Basic decision tree structure.

The main ideas behind the ID3 algorithm are:

- Each non-leaf node of decision tree corresponds to an input attribute, and each are to a possible value of that attribute. A leaf node corresponds to the expected value of the output attribute when the path from the root node to that leaf node describes the input attribute.
- In built system decision tree, each non-leaf node of tree correspond to the input attribute which gives most information about the output attribute amongst all the input attributes which were not considered yet in the path from the root node to that node.
- Entropy is used to determine how informative a particular input attribute is about the output attribute for a subset of the data under Consideration.

Database designing is one of the crucial tasks. First step in database design is to use data structures like Vectors and Lists. These come under Java Collection API. Secondly, a separate class is to be declared using these data structures.

C. DFD(Data flow Diagram):

The DFD (Data Flow Diagram) shows the flow of our system;

1) First of all we collect all sensors value as an input.
2) These collected values are send to Microcontroller with the help od ADC which converts the collected values Analog to Digital format
3) Microcontroller the forward data to the server.
4) Server has following multiple tasks
   i) Store sensors data to data base
   ii) Check threshold condition that whether or not capture data in greater than set threshold value
   iii) If capture data value is greater than set threshold value we perform all altering actions such as setting the delay timer of red light for more duration of time for the road with maximum traffic flow.

iv) We also apply Data mining to our database that is ID3 algorithm for future production of congestion and Data values to android phone users with the help of server.

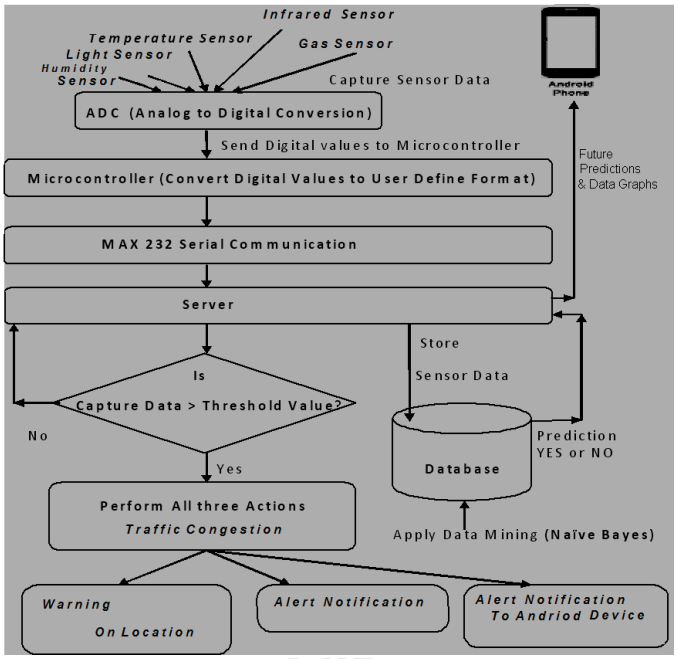

Fig.5 DFD

VI. RESULT

Proposed system takes input from different sensor that are Infrared sensor, Temperature sensor, light sensor and Gas sensor; these values are compared with the threshold Values which are already set, after comparing these value they group into three leads forming attributes, nodes and leaf nodes. Proposed system not only includes monitoring and controlling of traffic signal light but it also provides prediction of future congestion to the user by his/her android device.

Fig 6.Shows main menu screenshot of proposed project that displays different menus like Traffic light test with the help of which the healthy working of all signals lights at a function can be tested. Second is the system intelligent control that helps to view working of traffic signal light at associated junction or at base station.

Fig.6 Screenshot Main Menu

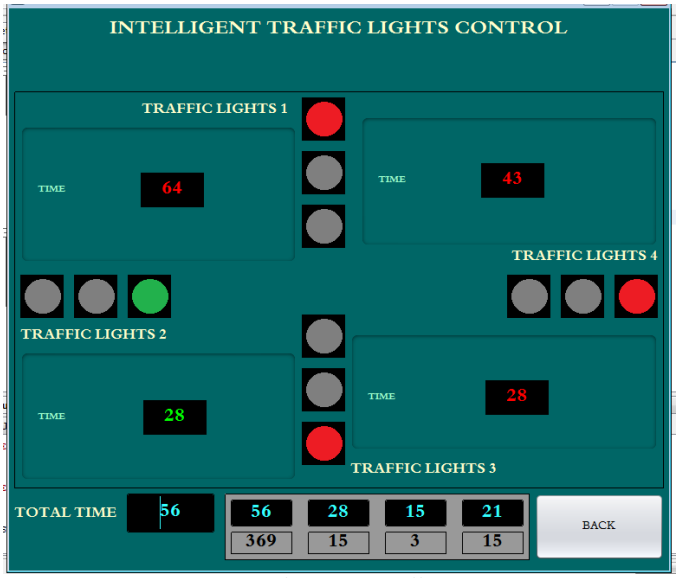

Fig.7 Screenshot of Intelligent traffic light control

Fig .7 shows system screenshot that contain control information of traffic light at associated junction. It displays four traffic lights at a junction each associated with four roads. The timer time of each road is displayed and glow of red - green and orange light can be observed. From the above timer control and vehicle, count it is clear that the system sets maximum delay for the road traffic light with maximum vehicle count and minimum delay is set for the traffic light for the road with minimum traffic flow.

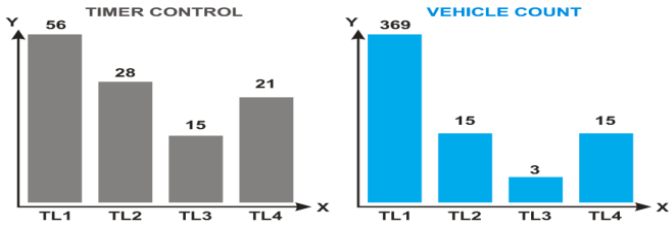

Fig.8 Data Graph

Fig 8. Shows that data graph of timer control and vehicle count. It can be clearly observed, the timer for heavy traffic flow is having maximum value as compared to the roads with low traffic flow.

VII. CONCLUSION

A novel technique is to be build will give best results to achieve a better understanding of the climatic condition and to alert users in gridlock situations. System includes not only monitoring and alerting of the traffic signal light but also it provides future predictions based on the data logs for possibilities of gridlock situations..

System not only monitors the traffic but also intelligently control the timer setting in order to avoid gridlock situation and traffic congestion. It allows the user to interact with the system via mobile portable devices like android phones. Hence we come to a conclusion that Real time intelligent traffic light monitoring and control system is a more advances technique that can provide us best features.

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