IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 4, Ver. II (Jul - Aug .2015), PP 87-96
www.iosrjournals.org

Adaptive Traffic Control System Based on Embedded Linux Board and Image Processing

Pranjali B. Patil, Atul A. Jadhav
Department of Electronics, Walchand College of Engineering, Sangli, India.
Department of Electronics, Walchand College of Engineering, Sangli, India.

Abstract:*The Traffic causes major concern in many of the developing as well as developed countries. The proposed system is designed to get the smooth and efficient traffic flow for daily life as wellas emergency conditions and also to provide safety in public transport. It is installed at the traffic signal intersection which controls the traffic light signal at the intersection.The proposed system provide the timing to traffic light signal depending upon the densities on the road instead of the fixed time frames, so which resultsheavily loaded side turned on for longer time as compare to the other lanes. Once the timing to each lane is allotted then as per that timing each lane is open in clockwise manner for some specified period of time. Afterthat period of time once again we allot the different time for each lane depending on their densitiesand this cycle is repeating endlessly. Here the density on the road is decided by the use of digital camera which continuously taking videos, and then afterword those video frames arefurther processed by the SBC board Raspberry-Pi with the help of OpenCV tool. In this proposed system GSM and GPS modules used to provide extra facilities to the emergency conditions. And at the same time, the proposed system also synchronizes traffic by storing and updating the traffic management database on the web server which adversely provides smooth and efficient traffic flow.*
Keywords: *Digital Camera, GPS, Kalman Filter, OpenCV, Raspberry-Pi.*

I. Introduction

The Transportation via road is majorly used mode throughout the world. This adversely increases the traffic on the road, and causes many of the traffic related problems.This traffic issue mostlyarises because of fixed time signal frame at the traffic signal intersection. These signals do not consider the actual condition on the road and allocate fixed signal time to each road which creates lots of issues. The region where lots of peoples travels through vehicles on the road, in that region this traffic impacts terrifically on people’s personal life, career, their future and even their safety. The main issue occurs because of this traffic on congested roadways is the delay. This delay because of traffic mainly impact at morning and at the end of the day, as because of this issue people can’t able to do their scheduled work at their scheduled time, also peoples are unable to estimate travel times. So it’s directly affects people’s daily life and this takes away from spare time to do other things all over the day. One more issue is arises because of this traffic while stopping and starting the vehicles at the traffic intersection, so it’s directly responsible for large amount of fuel burn rate while we compare this fuel burn rate with the fuel burn rate at open highway. As increase in fuel consumption, increasescosts for fuel so people have to pay extra money for fuel and it also boost-up the amount of emission which creates air-pollution and which causes the global-warming. This traffic jam is affects dangerously in emergency conditions, because emergency vehicle like ambulance, fire extinguisher van are incapable to react in a correct moment in time.

So to overcome many of the issues related to traffic, various techniques have been presented in literatureformaking our traditional traffic system more and more intelligent[1]. There are many methods like built a new roadways, use the LAN based or RFID based system but we can’t able to build a new roadways since there is a lack of free space availability and other methods like use of RFID sensor and LAN based system at the intersection are costlier than current existing traffic light control system, so in such a case we have to improve the current existing traffic light control system at the intersection.

So,in this paper we presented the proposed System which automatically changingthe trafficsignal lights at the intersection in clockwise manner depending upon the road density measured by digital camera. And furthermore proposed systemprovides availability of a free path to the emergency vans with the help of Global System for Mobile Communication (GSM) and Global Positioning System GPS, by automatically changing the traffic signal lights to keep the traffic line moving which provides the ease in traffic in case of emergency[1].The entire system traffic database is stored on the web server which provides the synchronization in traffic flow. So this results in the smooth and efficient traffic flow for daily life as well as emergency case.

The remaining parts of this paper are organized as follows.Section 2 Methodology reviews the related works of the proposed system. Section 3 System Design presents the description and actual working of proposed system. The experimental results are provided in Section 4 and the paper is concluded in Section 5.

II. Methodology

The proposed system is far better than any other systems as it makes the use of new technologies like SBC board Raspberry-Pi as hardware tool, and OpenCV for image processing taskwhich jointlyprovides a better efficiency than any other technologies.

The proposed system controls the traffic flow by providing appropriate signal time to each road so that the heavily loaded lane is open for longer time than that of the other lanes and at the same time it maintains the total time ratio at the intersection, so that the laneswhich having the less densities are also have the availability of free path without waiting for longer time. So to get the appropriate time to each road first we have to get the proper count of vehicles passed from each road.

This proposed system consists of four important components: The digital camera mounted and installed at each intersection, GSM & GPS engine and Raspberry – Pi for controlling traffic light signals[1][2]. Also we require software's as OpenCV for image processing task and PHP, MySQL, and HTML etc. for traffic database management on the web server

After the images have been captured by camera and processed by Raspberry-Pi, ON time is assigned to each traffic signal light according to its traffic density. Proposed system assigns highest priority for an emergency situation. So to handle emergency situation the Transmitter GSM & GPS engine is installed in an ambulance to send emergency message while receiver GSM & GPS engine is installed at each intersection. Each intersection is assigned with a unique code and these all intersections are further having the unique id for each road like as shown in the Fig.1, so if we considering the Fig.1 is having unique intersection code as 1 then its having the unique id for all the roads passing from the intersection 1 as ROAD A, ROAD B, ROAD C, and ROAD D shown in the fig.1which further help to turn the signal green.

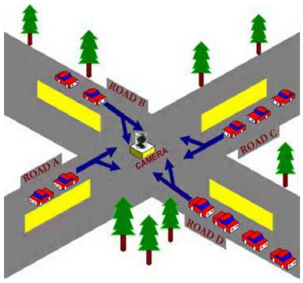

Fig. 1: Traffic control system

The unique code of each intersection and the unique id's for road passing through those intersections is saved at main server. As per, those code we can communicate with different intersections which gives the synchronization in travelling for main road traffic as well as emergency condition vans too. Proposed system allocates appropriate timing to each road or lane at intersection which results synchronization in traffic and smooth environment to those, who travel through the vehicle. Further system provides ease in traffic by storing and updating the important information in the form of traffic database at the main server, like how much time is allocated to each lane at different intersections, how much distance between different intersections, how many lanes at different intersection, average number of vehicles passing through the lane at some specified amount of time etc. The block diagram of Adaptive Traffic Control System (ATCS) is as shown in the Fig.2.

1.1 Experimental Setup

The Fig.1shows the traffic control system where its diagrammatical view is represented in the Fig.2. The digital camera is installed at the intersection which continuouslytaking video frames. The incoming video frames from the digital camera are processed by our SBC board Raspberry-Pi. Raspberry-pi processes these video frames by the use of OpenCV programming language and allocates the appropriate time to each road as per their densities on the road.

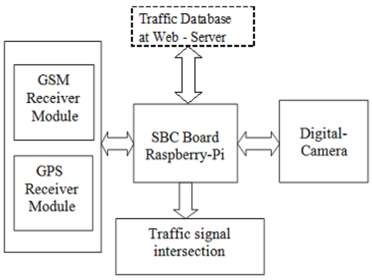

Fig.2: Adaptive Traffic Control System

So To get the exact vehicle count from each road we are using Kalman filter algorithm and Background Subtraction algorithm. Once we get the vehicle count then as per that count we allocate different time to different road at the intersection [1] [2].This all traffic related database like time allotted to each road at each intersection is stored and updated on our web server. Emergency conditions are handled by GSM and GPS modules, where the GSM and GPS transmitters are installed at the emergency vans and receivers are installed at the each traffic intersections so once the GSM and GPS transmitters transmits the message to their nearest intersection then automatically it is updated to our web server and immediately all the intersections are able to see the message that emergency vehicle is coming. The message coming from GSM and GPS transmitter holds the data like vehicles current location, destination location, and the path it prefer to reach up tothe destination location. So this data send by GSM and GPS module is used by our ITCS system to provide availability of free path to emergency vehicles whenever they require by assigning the highest priority to emergency case. In proposed system the extra facilities are also provided to these emergency vans like system provide shortest path information as per their destination, as in our proposed system the cities Google map is stored at our web server so that the driver of emergency van can decides by himself the possible shortest path for his destination,which further makes system more and more intelligent.

III. System Design

1.1 Vehicle detecting, tracking, and counting:

The digital camera is interface with Raspberry-pi, so the camera takes video frames, and those are processed by raspberry-pi. Todo all this image processing task proposed system uses a new image processing tool OpenCV and algorithm needed to track the vehicles are Kalman filter algorithm and background subtraction algorithm.

1.1.1 Opencv:

The proposed system uses OpenCV programming tool for image processing which is far better than the MATLAB programming tool. OpenCV is computer vision open source and machine learning software library. It is open source, so it is available at free of cost. This OpenCV library includes more than 2500 optimized algorithms and functions, which includes set of both computer vision and machine learning algorithms. These algorithms are very useful as those can be used to track camera movements,classify human actions in videos, detect and recognize faces, identify objects, track moving objects, extract 3D models of objects, find similar images from an image database, stitch up images jointly to create a high resolution image of an intact scene, produce 3D point clouds from stereo cameras follow eye movements, also in OpenCV we are able to remove red eyes from an images taken using flash, etc. OpenCV is really a fast enough while it comes to the speed of execution. As OpenCV is mainly a library of functions which are written in C, C++, and it is runs under Windows, Linux, Mac OS X, and Android. OpenCV has active development of interfaces for Python, Ruby, Java, and other languages. The memory required to run the code built in OpenCV is far less when we compare it with the memory required to the code which is built in MATLAB.

1.1.2 Kalman Filter Algorithm:

The Kalman filter is a set of mathematical equations [3] [4]. It is very influential because it provides estimations of past, present, and future state. It is most popular Optimal-Estimator. It is Optimal in the sense that if all noise is Gaussian noise, Kalman Filter minimizes the mean square error of estimated parameters. If noise is not Gaussian, then also Kalman filter is useful because it is not only the best Linear-estimator but also the good non-linear estimator. Kalman filter provides us the best estimated data from the noisy data. It is Recursive in nature so that there are unremitting measurements are processed as they arrive, those all are the reason why we prefer Kalman filter for vehicle tracking purpose. The short introduction about the Kalman filter is given below
The Kalman filter is basically depends upon two types of equations,

- Time – Update Equation:
- Measurement – Update Equation:

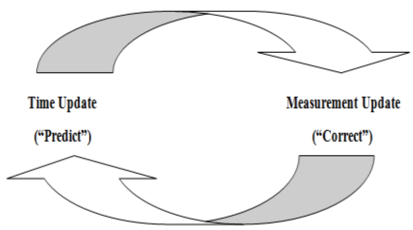

Fig.3: Kalman filter life cycle

These two equations are acts as the predictor and corrector type of equations respectively, because the time-update equation mainly used to predict the next position of the moving object while measurement update equation can corrects the predicted position with the help of feedback factor and actual measurement at that time. The life cycle of the Kalman Filter Algorithm is represented in the above Fig. 3,

1.1.2.1 Process And State Model:

Consider the discrete-time controlled process which is explained with the help of following linear stochastic equation (1) as:

$$x_{k+1} = A_k \cdot x_k + Bu_k + w_k \quad (1)$$

Here, x_k represents the state variable at time step k, the random variable w_k represent process noise, A and B are n × n and l × n matrix coefficient related to the difference equation (1) of state at time step k and control input respectively.

Now, the measurement of the system can be explained as:

$$z_k = H_k \cdot x_k + v_k \quad (2)$$

Here, z_k represents the measured value at time step k, H is the m × nmatrix coefficient to the measurement statez_k, and the random variable v_k represent measurement noise of the system.

The random variables$w_k$and $v_k$are assume to be independent on each other, and so that these white Gaussian noise have their covariance matrices as Q and R, and these Co-variance matrices are represented in the equation (3) and (4) respectively as,

$$E[w_k \cdot w_i^T] = \begin{cases} Q_k & i = k \\ 0 & i \neq k \end{cases} \quad (3)$$

$$E[v_k \cdot v_i^T] = \begin{cases} R_k & i = k \\ 0 & i \neq k \end{cases} \quad (4)$$

So the equation (5) depending upon the above equation represent that Co-variance matrix between w and v is alw

ays equal to zero for all the k and i,

$$E[w_k \cdot v_i^T] = 0 \quad (5)$$

1.1.2.2 Estimation Of Origins Of Kalman Filters

The current state is x_k at time step k then its prior state at time step k is considered to be $\hat{x}_k^-$ and its posterior state estimation at time step k gives measurement z_k is$\hat{x}_k$, so the prior and posterior estimation of error is given respectively in equations (6) and (7) as,

$$e_k^- \equiv x_k - \hat{x}_k^- \quad (6)$$

$$e_k \equiv x_k - \hat{x}_k \quad (7)$$

So the prior and posterior estimation of the error co-variance is given in equations (8) and (9) as,

$$P_k^- = \mathrm{E}[e_k^- {e_k^-}^T] \quad (8)$$

$$P_k = E[e_k {e_k}^T] \quad (9)$$

Now to get the exact prediction of a moving object we have to find out the most important factor from the Kalman filter algorithm is Kalman Gain or Blending factor K which minimizes posteriori error co-variance,

$$K_k = \frac{P_k^- H_k^T}{H_k P_k^- H_k^T + R_k} \quad (10)$$

From the above equation (10) we may see that if $R_k \to 0$ then, the actual measurement z_k is considered and trusted to be more and more otherwise if $P_k^- \to 0$ then prediction measurement $H_k \hat{x}_k^-$ is considered and trusted to be more and more.

So, from all the above equations we may conclude for the Kalman filters time-update and measurement-update equations which are used as Predictor and Corrector equations respectively,and we assume zero value for all constants for better result.

1.1.2.3 Time-Update Equation:

The equations which we actually use at the time of programming are represented by following equations, Prediction for the state ahead is,

$$\hat{x}_{k+1}^{-} = \hat{x}_k \quad (11)$$

Prediction of the Error co-variance ahead is,

$$P_{k+1}^{-} = P_k + Q \quad (12)$$

1.1.2.4 Measurement-Update Equation:

Kalman Gain given by,

$$K_k = \frac{P_k^-}{P_k^- + R} \quad (13)$$

Update estimation of state with measurementz_k represented by,

$$\hat{x}_k = \hat{x}_k^- + K(z_k - \hat{x}_k^-) \quad (14)$$

Update estimation of Error co-variance with measurementz_k represented by,

$$P_k = (1 - K_k)\, P_k^- \quad (15)$$

1.1.3 Algorithm For Tracking The Moving Vehicles:

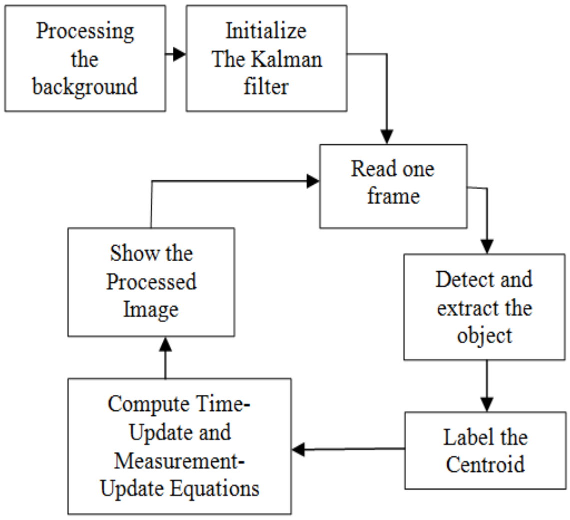

Fig.4:flowchart to track and count the vehicles

Vehicles detection must be executed at different surrounding where the traffic signals light and the traffic status changing. In the proposed system, we accept the traffic video through the digital camera and convert video into frames remove reference backgrounds [2] and achieves detection of moving objects, explained in following three stages,

1) System Initialization: System gets initialized and set up in this stage. The digital Camera endlesslyrecords the stream of data and then sends this information to the system for analysis.
2) Background Subtraction: In this stage, a set of video frames are taken into center of attention and on consecutive analysis and operations background subtraction takes place.
3) Vehicle Detection: In this stage, using the subtracted background image obtained after background subtraction method all the moving vehicles or the objects can be detected, tracked and counted.

The proposed system works in real-time camera mode. Here in the Real time camera mode application we can provide the video frames through the camera and tracks the vehicles and after that those vehicle are counted. Once the vehicles are detected we bound the rectangle around the detected vehicles by calculating the Centroid of that vehicle, after bounding rectangle around detected vehicle we increment the count of the rectangle to detect and count the next vehicles. This process is continues until we forcefully stop the camera and allocate the timing to that respective signal and once the process iscompleted camera will again takes the video frames and this process is continues endlessly.

1.1.4 Result Of Vehicle Tracking:

1.1.4.1 Camera Setting:

Before capturing the video frames from the web camera, it is predictable to check current screen resolution. Ifthe resolution is less than 1024 x 768 this application may not produce desired results. So we have to change the resolution upto 1024 x 768 or higher for finest performance.

1.1.4.2 Object Detection:

Theobject detection part OpenCV library is used for coding purpose. System is designed to start getting images from digital camera. Every frame will be processed to find a moving object in the video. So to process the frames first we have to convert the RGB images to Gray scale images because the Gray scale images uses only 2 colors either white or black so it is easy for processing further on the image and also memory require for gray scale image at time of process is less. Once the RGB to Gray scale conversion is complete then we can go for background subtraction method to detect the vehicles. Here the first frame is subtracted from the current frame so which gives the result as vehicle is to be detected, which is shown in the following Fig. 5 and Fig.6,

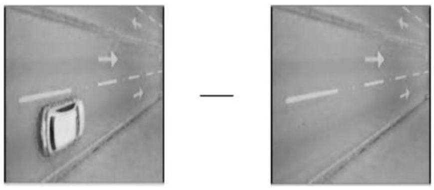

Fig.5: Background Subtraction

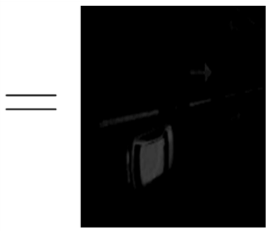

Fig.6: Result of background subtraction method (BCM)

The Background Subtraction Method (BCM) results the image which are having the images in Gray format where the vehicle is in the white color while the background image is in the black color.Sincethe image contains some portion is in white color so to remove this again we have to convert this resultant image into binary format.This result the image in which the detected vehicle is represented by several white parts and the background image are in black.So to get the single vehicle as a single white part we apply morphological operation which consist erosion and dilation operations respectively. Binary images may contain copious imperfections. In particular, the binary regions produced by simple thresholding are distorted by noise and texture. Morphological image processing pursues the goals of removing these imperfections by accounting for the form and structure of the image. These techniques can be extended to gray scale images. So the result of the morphology is shown in following Fig.7,

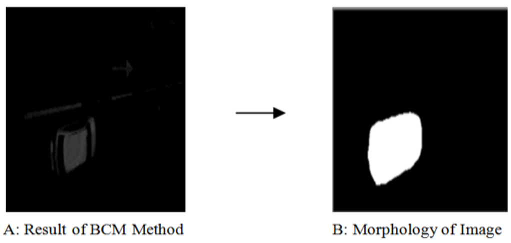

Fig.7: Morphology Result

1.1.4.3 Object Tracking:

Once the vehicle is detected then we have to track that vehicle continuously until that vehicle is moved out of frame and then we give count to that vehicle. So to do that we have to find out the Centroid of that detected vehicle and then as per that we bound rectangle around that vehicle. Once the Centroid of the detected vehicle is obtained then we apply Kalman filter algorithm for tracking that vehicle so the output obtained is represented in Fig. 8,

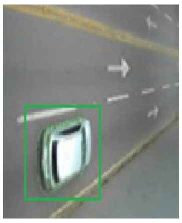

Fig.8: Tracking of moving vehicle

1.1 Algorithm For Allocation Of Time To Different Road At Intersection:

Once the count for different road at traffic intersection is obtained then proposed system allocates the different timing to each road (lanes) present at the intersection as per their densities, by applying the formulae explained below,

- Total Signal Time = sum (Allocated time to different road + Alert time);
- Allocated time = min (rows*time, Threshold time);
- rows = round (Vehicles/lanes);
- time = (Avg speed / Distance);
- Distance = (Buffer distance + Avg vehicle length);

The Buffer distance is the safety distances which separate two cars from each other's, and on an average we consider this distance two meters. The Avg vehicle length is considered to be four meters. Therefore the Distance is the total distance needed for a vehicle to cross the intersection which is six meters on an average. Avg speed is the average speed of the vehicles when they start to depart the signal area. So it is assumed to 20km/hr. which results the time, time is total time required by the vehicle to cross the intersection which is supposed to be 0.93seconds (20km/hr / 6m), lanes represent the number of roads in an intersection. Vehicles are the number of vehicle estimated with the help of digital camera. Based on these two parameters the rows parameter estimated.

Finally we calculate for Allocated time which is the actual time we allocate to particular road depending on its density to clear the traffic. Here we assume threshold as 15seconds.

The Total Signal Time is calculated as summation of Allocated Time to different roads and the Alert Time. The Alert Time is the total transition time for yellow light.

1.2 Synchronization Of Traffic By Managing Traffic Database At System:

Once allocation of time is obtained then we update this information to our database and web server where we already stored the important traffic database with the help of Apache, MySQL, and PHP, which result in synchronization of traffic at traffic signal intersection and also at the main road traffic.

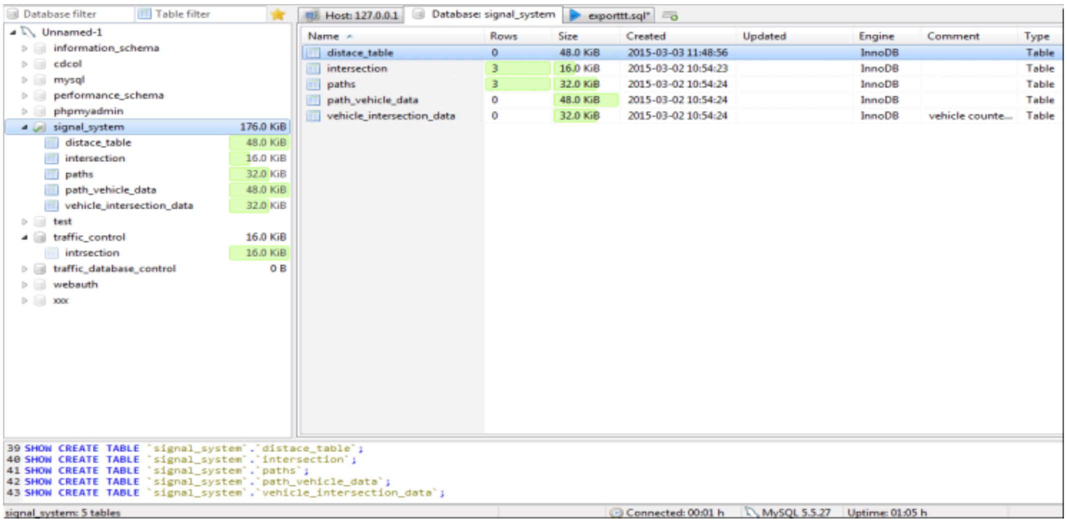

Fig.9: Database with all tables for synchronization of traffic.

The above Fig.9 represents the database we have to store on our SBC Board and which is used by our system to provide ease in traffic. The database shown in Fig.9 holds different tables like distance_table, intersection, paths, path_vehicle_data, and vehicle_intersection_data. The information hold by these tables is described below,

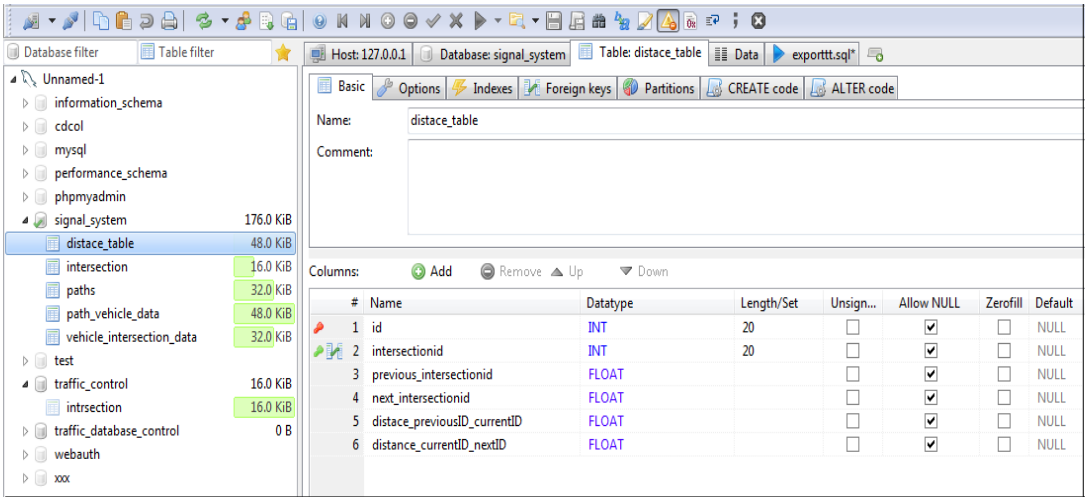

Fig.10:distance_table stored in the database

The above Fig.10 represent the distance_table which holds the information about the intersections present in the city like id of current intersection, id of its previous intersection, and next intersection, then distance between them etc. which helps to get ease in traffic further. Here as shown in the Fig.10, id in the distance_table is unique key and intersectionidis a Foreign key whichreferenced to the id of intersection table.

Similarly the other tables also hold important data which is jointly gives synchronized, smooth, and efficient traffic flow explained as,

Table description:

1) intersection

- id(primary key auto increment)
- name
- longitude latitude
- paths

2) paths

- id(primary key auto increment)
- name
- intersectionid (foreign key references intersection table column id)

3) vehicle_intersection_data

- id (primary key auto increment)
- time
- total_count
- intersectionid (foreign key references intersection table column id)

4) path_vehicle_data

- id (primary key auto increment)
- pathid (foreign key references paths table column id)
- count
- vehicle_intersection_id (foreign key references vehicle_intersection_data table column id)

1.3 Handling Emergency Conditions:

As we discussed above by the use of this database we manage daily life traffic very efficiently but for the case of emergency vehicles like ambulance, fire-extinguisher vans, VIP vans etc. we use GSM and GPS module. The GSM and GPS modules transmitters are installed at the emergency vansand receivers are installed at the intersection. So once they transmit the message to their nearest intersection this message displayed on our web server, after that every intersection of ourcity get this message and gives availability of free path to these emergency vehicles whenever they require. The message sent by GSM module holds the information like their source and destination location, path they follow to reach upto the destination location etc. In case the GSM module also provide the calling facility, so the driver of emergency vehicle also able to call and seeks the help.

Fig.11: Calling through GUI of GSM module installed at emergency van

Once the message sent by the GSM to nearest intersection then by the use of GPS module installed at the emergency van all intersections continuously track that van. Proposed system assigned with highest priority for emergency van so system give the availability of free path to these emergency vans whenever they require.

IV. Result

As we discussed above by the use of OpenCV tool we detect, track and count the vehicles through the digital Camera. So the result obtained for counting the vehicles and allocating time to different road is shown in the below Fig. 12,

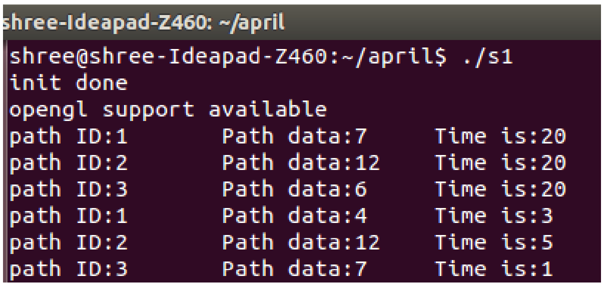

Fig.12: Vehicle count and allocating time to 3 different roads at intersection as per their density

The web page which developed for traffic control and synchronization is,

Fig.13: Web page for traffic control.

V. Conclusion

Here we design and implement the system which successfully detect track and count the vehicles, this system based on image processing technique and uses OpenCV as a software tool whereas the algorithm used is Kalman filter algorithm, and Background Subtraction algorithm. For moving vehicle detection first we apply the background subtraction method and then we apply Kalman filter algorithm for tracking that vehicle continuously. The single digital camera used by system for measuring the density of vehicles on the roads at an intersection.The system is tested under various crowd conditions and found to be efficient as compared to other sensor based systems. As system stores and update database so provide the efficient traffic flow throughout the city. The emergency condition is handled further by providing highest priority to emergency vans, and tracking them continuously once proposed system receives message from emergency vans. So the proposed system provides better result than any other systems.

References

[1]. Farooq, U.; Atiq, H.M.; Asad, M.U.; Iqbal, A.; Azmat, Z., "Design and Development of an Image Processing Based Adaptive Traffic Control System with GSM Interface," Machine Vision, 2009. ICMV '09. Second International Conference on , vol., no., pp.166,171, 28-30 Dec. 2009

[2]. Ospina, E.; Tascon, E.; Valencia, J.; Madrigal, C., "Traffic flow control using artificial vision techniques," Computing Congress (CCC), 2011 6th Colombian , vol., no., pp.1,4, 4-6 May 2011.

[3]. Zhijun Qiu; An, D.; Yao, D.; Zhou, D.; Bin Ran, "An adaptive Kalman predictor applied to tracking vehicles in the traffic monitoring system," Intelligent Vehicles Symposium, 2005. Proceedings. IEEE , vol., no., pp.230,235, 6-8 June 2005

[4]. Lei Xie; Guangxi Zhu; Yuqi Wang; Haixiang Xu; Zhenming Zhang, "Real-time vehicles tracking based on Kalman filter in a video-based ITS," Communications, Circuits and Systems, 2005. Proceedings. 2005 International Conference on , vol.2, no., pp.,886, 27-30 May 2005.