Smart Intersection Management system

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Abstract: The congestion of the urban traffic is becoming one of the critical issues with increasing population and automobiles in cities. Traffic jams not only cause extra delay and stress for the drivers, but also increase fuel consumption, add transportation cost, and increase carbon dioxide air pollution. The traffic controller is one of critical factors affecting the traffic flow. The conventional traffic patterns are nonlinear and complex and time dependent rather than traffic dependent. Here we are proposing a traffic based feedback intersection system which changes the time of green and red light with respect to the traffic flow rather than time. The "SIMS" utilizes very basic hardware to ensure that costs are reasonable & the maintenance is low. The entire project uses Image processing as its principle. The hardware used are Camera, Stepper Motor, Raspberry Pi, Arduino Uno, LCD, LED. This solution to the ever increasing urbanization would help in lowering the level of traffic congestion in many large cities, like Bangalore which experiences a very high level of traffic congestion that has been unprecedented. The result is that most road networks in urban areas would provide an optimal transport system and would also reduce the air pollution, fuel consumption and various other negative factors. Also it would ensure a reduction in accidents due to inefficient traffic management.

Keywords: nonlinear, traffic dependent, Image processing, Raspberry Pi, Arduino Uno, traffic congestion.

I. INTRODUCTION

With the rapid growth of industrialization, urbanization, population a tremendous growth has occurred in the number of vehicles, leading to the increased traffic. It further causes traffic rule violation, heavy traffic signals, accidents, traffic jam which also causes a lot of wastage of time. The traffic lights established these days are static i.e. they are unable to adjust the time duration of the signals according to the density of the lane as well as unable to prioritise the emergency vehicles. Sometimes the vehicles on the red light lane have to wait for green signal even though there is no traffic where the green signal is allotted. It results in the loss of valuable time as well as loss in fuel consumption resulting pollution. Travelling to different places within the city is becoming more difficult, there is a loss in productivity from workers, people loose time; trade opportunities are lost, delivery gets delayed, and thereby the costs goes on increasing which ultimately leads to frustration and imbalanced life. Therefore many countries are working on efficiently managing their existing transportation systems to render improved mobility and safety. Hence an automatic traffic management scheme which works on real time traffic is becoming prominent. The simplest form of traffic management includes human in the system. In this scheme, a traffic officer is placed on each and every cross-section of the roads; the traffic police control the flow of traffic. In time of congestion she/he gives the signals to the vehicle driver whether to stop or drive. She/he is also able to recognise emergency case, so she/he can choose which lane needs more priority than other. This scheme is most efficient than any other technique. But as it includes human as a part of system this scheme is inadequate. Efficiency of system depends on experience and capability of the person.

In order to remove the weak link i.e. human in above system, an automatic traffic management scheme is suggested. The system which we see every day includes simple three colour traffic signal. Generally for each lane 120 seconds of green light is on. Before green light, yellow light flashes for 20 second, signifying to start the vehicle and be ready to go. For all the time red light is on, indicating each vehicle to stop. This system cannot identify emergency vehicle, it treats normal car and ambulance in the same way. So there are chances of delay in the emergency services.

II. OBJECTIVE

Currently the traffic control system in place in our country is non-flexible and non-adaptive to the ever growing number of vehicles on the road. It does not take into account the changing density of traffic during the different hours of the day. Consequently, the roads get congested frequently and intersections get blocked.

Time and fuel, two highly important resources get wasted in this inefficient working of the present-day system. In this article, we propose a dynamic system that overcomes all these drawbacks.

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- Our system uses cameras installed at the red lights and intersections to monitor the traffic dynamically.
- It then processes this information using image processing,
- Computes the volume of the real time traffic, sets the timer of the signal accordingly.
- Simultaneously, it monitors if there is any scope of congestion at the intersection and adjusts the timer to prevent it.

The entire system works autonomously and has a quick turnaround time, saving critical resources at every junction.

III.LITERATURE REVIEW

In [1], the proposed system makes use of the background differencing of an empty lane road. The resulting output is fed to the microcontroller system for traffic light control system on real time data.

In [2], a method of real time area based traffic estimation; using image processing for intelligent traffic control system is described. This paper makes use of edge detection. The more the vehicles in a road, the more is the area of the edges of the vehicles which means the traffic congestion is more. Thus more duration can be allotted for that road.

In [3], a method is proposed for determining traffic congestion on roads using image processing techniques and a model for controlling traffic signals based on information received from images of roads taken by video camera. Here the empty road will be the background image and subsequent frames from the video camera will be the foreground image. By subtracting background image from the foreground image we can find out traffic density present in a frame.

In [4], the system will detect vehicles through images instead of using electronic sensors embedded in the pavement. A camera will be installed alongside the traffic light. It will capture image sequences. Setting image of an empty road as reference image, the captured images are sequentially matched using image matching. For this purpose, edge detection has been carried out using Prewitt edge detection operator and according to percentage of matching traffic light durations can be controlled.

IV.METHODOLOGY

RGB coloured image are captured using the camera and sent to the processing unit. There it is converted into a gray scale image which undergoes binary conversion. The image being binary image, it either has pixels with value of 255 or 0, no grey levels. The image is then processed to calculate the white and the black area which is used to calculate the density of the traffic. The calculations are then used to assign sequences to switch the light. Figure 1 shows the basic diagram of the proposed system.
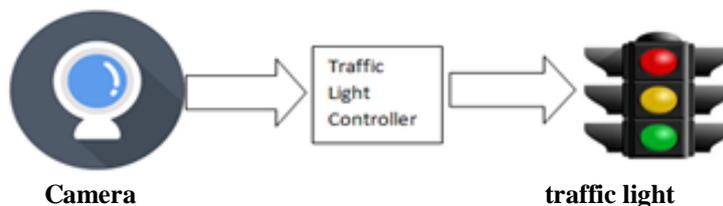

Fig 1: Basic diagram

A.   Block diagram:

Figure 2 shows the block diagram of the proposed model. The whole model is placed at the intersection of 4 traffic lanes: lane 1, lane 2, lane 3 and lane 4.
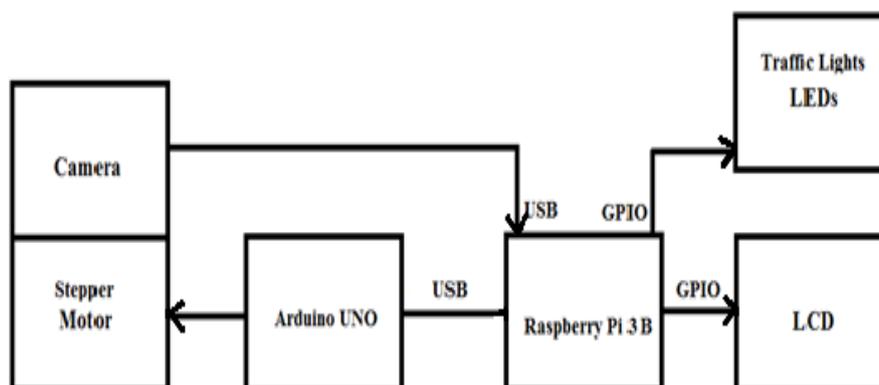

Fig 2: Block diagram

The 8 megapixel camera is placed on the NEMA 17 stepper motor. The stepper motor is programmed with Arduino code. The Arduino Uno and the Raspberry pi 3B v1.2 module are serially connected using USB cable for synchronization of operation between the camera and the stepper motor. The camera captures the image of a particular traffic lane and sends the signals to the Raspberry Pi through USB cable. Raspberry Pi processes the signals using the code in Python language. Python is used because it has many built in libraries to process the image and the standard English words can be used for coding.

The Raspberry Pi performs the following basic steps with the help of Python code:
1. The first step is to get the Traffic length (T_{Len}) and traffic density (T_{Dens}) using image processing techniques like:
- Cropping: The photo captured from the camera is cropped for the required region of the road.
- Image segmentation: It is used for partitioning the digital image into multiple segments (sets of pixels known as super pixels) thus locating the vehicles and their boundaries (lines, curves, etc.).

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to properties such as colour, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristics [5].

- Filtering: It is a technique for modifying or enhancing an image to emphasize certain features or remove other features. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement [6].

- Otsu's thresholding: This is used to automatically perform clustering based image thresholding or the reduction of a gray level image to a binary image. It is done by using numpy library in Python. In global thresholding an arbitrary value is taken as threshold value. If pixel value is greater than a threshold value, it is assigned one value (may be white), else it is assigned another value (may be black).In Otsu binarization, bimodal image is considered. It is an image whose histogram has two peaks. For that image, an approximate value in the middle of those peaks is taken as a threshold value. Otsu's thresholding automatically calculates a threshold value from image histogram for a bimodal image. Figure 3 represents global thresholding with noisy image, Otsu's thresholding with noisy image and Otsu's thresholding with Guassian filtered image [7].
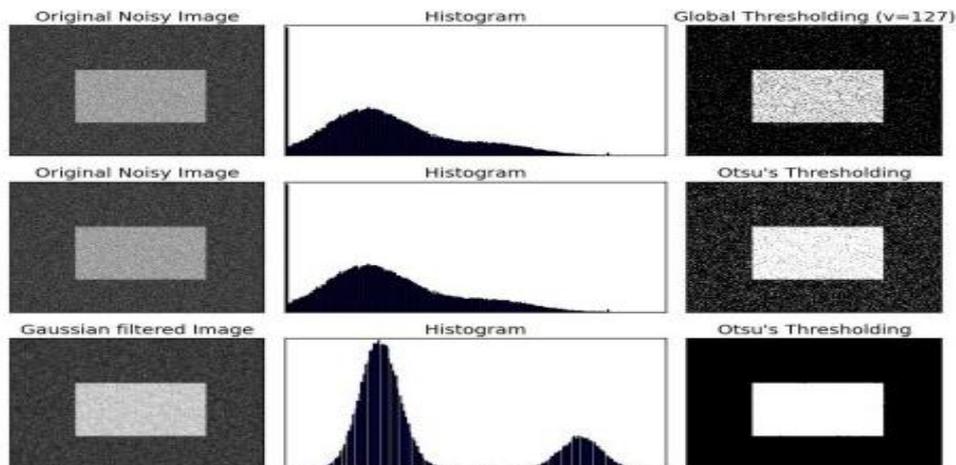

Fig 3: global thresholding with noisy image, Otsu's thresholding with noisy image and Otsu's thresholding with Guassian filtered image

- Counting the number of white pixels out of the total number of pixels and counting the number of objects using edge detection.
2. The second step is to use the data collected above to change the time of the traffic signals as green for a specific direction of traffic at an intersection.
3. Wait for a time duration T_{dur} that is a dynamic value, calculated according to the traffic conditions in the allowed directions. The maximum permissible period for one pair of directions is fixed (at T_{max}) but can be reduced to decide T_{dur} as the traffic in the allowed direction decreases.
4. The amount of time that a signal turns green is decided by the following equation:

$$T_{dur} = T_{max} - (T_{max} * k)$$

Where k is decided from the equation

$$k = \text{normalized density} + \text{count}$$

Where

$$\text{Normalized density} = \text{calculated density/maximum density}$$

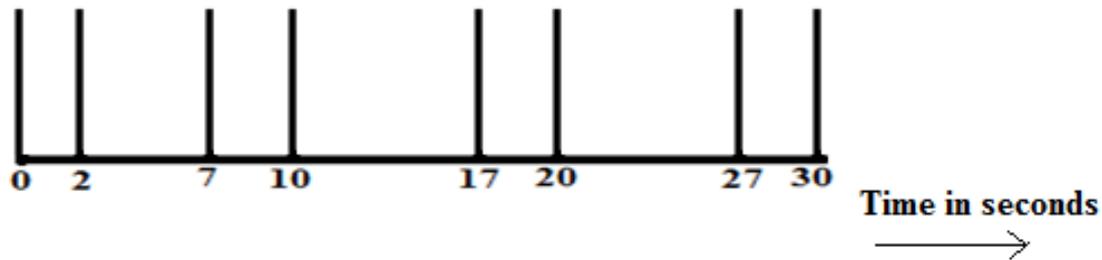### B.   Timing Diagram:

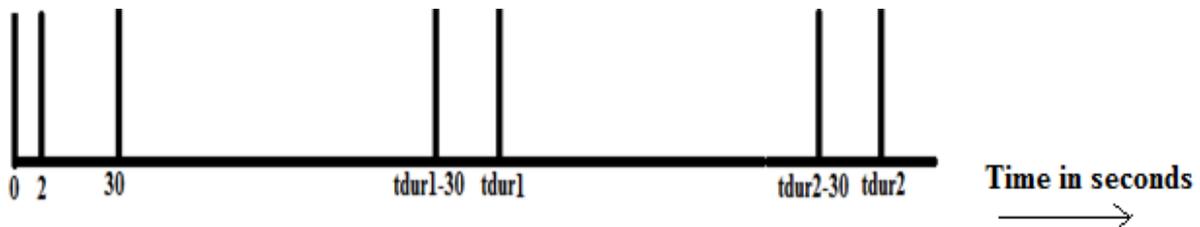Fig 4: Sequence of operation within 30 seconds of time

Fig 5: Timing Diagram of LED light control

Steps:
In figure 4, the sequence of operation within first 30 seconds of time is shown.
At 0, Lane 1 photo is taken.
At 2, Stepper motor rotates 90 degree anticlockwise.
At 7, Lane 2 photo is taken.
At 10, Stepper motor rotates 90 degree anticlockwise.
At 17, Lane 3 photo is taken.
At 20, Stepper motor rotates 90 degree anticlockwise.
At 27, Lane 4 photo is taken.
At 30, Stepper motor rotates back to its initial position clockwise.

In figure 5, the entire process flow is shown.
1. At 0, all the 4 lanes will have traffic light as red. The camera initially faces towards lane 1.
2. Between 0 and 2, the camera captures the photo of the traffic in lane 1.
3. At 2, the stepper motor connected to the Arduino Uno rotates by 90 degree to face the lane 2 traffic. Similarly, the camera and the stepper motor operate to capture the pictures of lane 2, lane 3 and lane 4 traffic respectively, as per the sequence of steps mentioned for figure 4.
4. At 30, the captured images are given to the Raspberry pi 3 B v1.3 module through USB cable. The Raspberry Pi module processes the captured images and the resulting signals are passed to the LED and LCD display through GPIO pins of the Pi module. The LED shows the green signal for the lane with maximum traffic for T_{dur} time and red signal for rest of the lanes. T_{dur} can be in between T_{max} = 120 seconds or T_{min}= 35 seconds of time. In the first case, $T_{dur} = T_{dur1}$. The LCD acts as a timer and shows the countdown values from T_{dur1} to 0.
5. t_{dur1}-30, The procedure for the evaluation of the next traffic scenario should start before 30 seconds of the completion of T_{dur1}. Therefore the stepper motor starts to rotate and the camera starts to capture the photos again.
6. At t_{dur1}, for the first set of images, the green signal to the maximum traffic lane ends in LED and timer stops in LCD. The Raspberry Pi evaluates the maximum traffic lane for the second set of images and gives the green signals to LED for T_{dur2} time and the T_{dur2} time for LCD.
7. At t_{dur2}-30, The stepper motor runs and the photos are taken for next 30 seconds for the 3rd set of traffic scenario.
8. At t_{dur2}, for the second set of images, the green signal to the maximum traffic lane ends in LED and timer stops in LCD. The Raspberry Pi evaluates the maximum traffic lane for the second set of images and gives the green signals to LED for T_{dur3} time and the T_{dur3} time for LCD and the process continues.
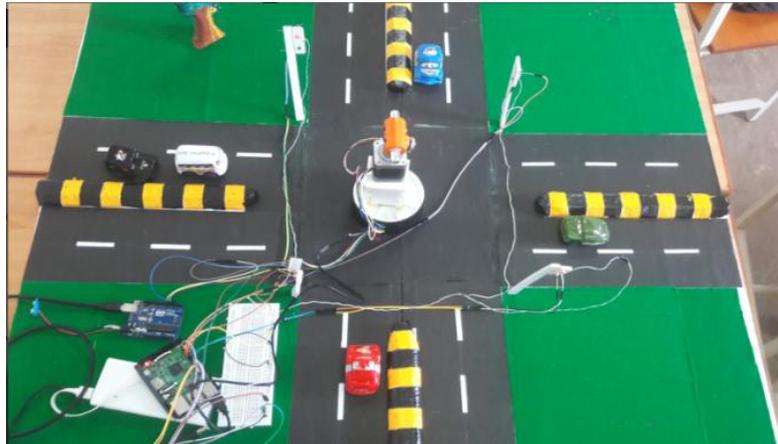
Fig 6: the experimental setup

V. ADVANTAGES & DISADVANTAGES

A.   Advantages

The following are the advantages of the proposed system:

- By alternately assigning right of way to various traffic movements, signals provide for the orderly movement of conflicting flows. Thus efficient management of the traffic in the intersection can be achieved.
- The time being wasted in automatic traffic control by providing green light on the empty road is avoided.
- avoids traffic jams
- The resources such as petrol, diesel and natural gas can be saved.
- The optimization will lead to faster transportation of goods.
- Cameras installed can be used for security purposes.
- Avoids accidents

B.   Disadvantages

There are some demerits in the proposed system:

- The system is efficient up to 80% as the system has difficulty to detect black coloured vehicles.
- Requires high definition camera

VI. RESULTS AND DISCUSSIONS

The images of traffic in lane 1, lane 2, lane 3 and lane 4 are captured using the camera mounted over the stepper motor at the intersection. Figure 6, figure 7, figure 8 and figure 9 show the captured image of lane 1, lane 2, lane 3, lane 4 in the camera's view respectively.
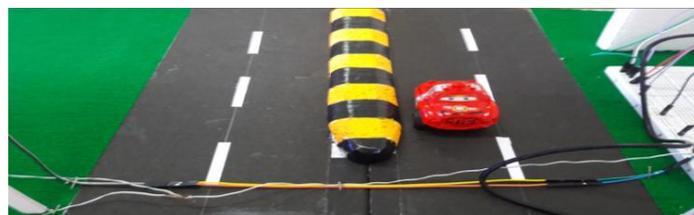
Fig 6: Lane 1 image
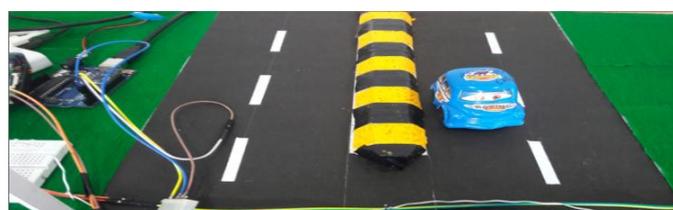
Fig 7: Lane 2 image

Fig 8: Lane 3 image

Fig 9: Lane 4 image

The segmented-images of traffic in lane 1, lane 2, lane 3 and lane 4 are as shown in figure 10, figure 11, figure 12 and figure 13 respectively.
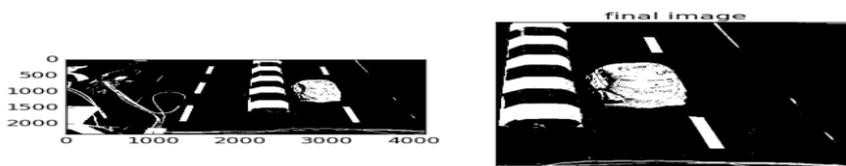

Fig 10: Lane 1 segmented image

Fig 11: Lane 2 segmented image

Fig 13: Lane 3 segmented image

Fig 14: Lane 4 segmented image

Figure 15 shows the simulation result after image processing for the images in figure 11, 12, 13 and 14.

Fig: 15 Simulation Result

VII. CONCLUSION

The proposed traffic control system is adaptive for the dynamic and real time traffic. It can be used to easily determine the traffic density according to the simulations so far. This area based traffic system can be used in densely populated areas where the number of automobiles is increasing gradually. Our system will play an important role in estimating traffic congestion to control traffic signals but it can still be improved by

- including features such as emergency vehicle detection in the case of ambulance
- using better algorithms
- learning the traffic hours.

ACKNOWLEDGMENT

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