Design of an Automatic Traffic Control System with Real Time Vehicle Density Analysis

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Abstract*: *Growth in developing countries forcefully leads their roads becoming increasingly congested thus bringing traffic to a standstill. There are two major measures that can address this issue viz. manual and automatic approaches. Because of its inefficiency, manual approach is not considered under the preview of this study and the automatic approach, which is the focus of this study, can further be classified into two viz. timer based and density based approaches. Timer based approaches are primarily static in nature and hence cannot consider real time requirements. Incorporating Density analysis on to the problem under preview adds dynamism to the solution and in the proposed study, traffic signals are controlled by considering real time density of vehicles on each roads. After capturing real time images and performing appropriate preprocessing, density of vehicles are measured using Canny Edge detection approach; which is used as a parameter for later decision making. Considering density parameters alone may lead to starvation to certain roads and here in the proposed study, authors consider a weight factor to propose a better solution. A prototype was developed using Arduino mega 2560 board, Webcams and Airplane 9g Mini Servo - SG-90 and led lights and it was observed that the efficacy of the proposed system is higher while comparing it to other prevailing methods.

***Keywords*: traffic controlling, traffic congestion, real time traffic control**

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I. INTRODUCTION

Traffic congestion is one of the serious issues human beings confront in their everyday life. The main reason for this is the vast increase in population and the proportionate increase in the density of vehicles on road. Further, to add to it, the roads are not developed proportionately. According to Times of India's survey of 2016, more than 53,700 vehicles are registered, across India, every day. The ever increasing population of vehicles may choke the life in many cities and currently, we use two mechanisms to control the traffic congestion. First, is the manual controlling mechanism, where police personnel controls the traffic using hand signs, whistle, etc. Problem with it is that it is not viable to manually control traffic in large cities for scares of manpower [2]. Second is the automatic traffic controlling which uses signal lights to control traffic congestion. These are based on timers, where each road gets a fixed quantum of time for it to flow traffic. The main drawback of automatic traffic controlling is the false allocation - where there may be a green signal on an empty road, which causes vehicles in other roads wait unnecessarily, thus attributing to the traffic congestion. These facts reiterate that we need a much better traffic controlling system than the prevalent one to control traffic efficiently and thereby reducing traffic congestion. To overcome these problems, the current study is proposed which uses density analysis.

In this study, images are captured, from real-time traffic, using high resolution cameras fixed at a higher position in a traffic junction. Density count of vehicles from each road is extracted from these images, using various image processing techniques. These extracted details can be used extensively for the efficient management of traffic light signals. These automations can minimise the traffic congestion and will lead to an efficient system, than the timer based and the manual systems. Another merit of this study is that, manpower can be minimised substantially, since, it requires minimal human intervention. Unlike other studies, real-time density of vehicles to control the traffic are considered here thus eliminating the problem of false allocation.

The rest of this paper is organised as follows: section II explains current status of this study whereas section III explains the materials and methods used in this work. Finally, section IV concludes the paper followed by the key references used in the work.

II. REVIEW OF LITERATURE

Neem Abbas et al. [1] proposed an approach for real-time traffic analysis. Initially, the system captures empty roads, say reference images, which are used as a bench mark for later traffic density analysis. Images of the roads with traffic are captured periodically and are converted into grayscale format. Further, system crops out unnecessary regions from these grayscale images thereby selecting the target area by designing image cropping algorithms in Matlab. The binary image of the reference image is formed where the road area has been shaded white and left over region as black. Multiplication of reference image with the cropping black and white image will result in the final desired target area. Next step is object detection. It captures traffic images and then converts it into grayscale image. Now the absolute difference between the reference image and traffic image is determined. The result (vehicles) in the target image may not be clear, since it is a grey scale image. So as to improve the visibility of vehicles, the difference image is converted into the binary image based on a threshold value. In order to determine only vehicles in the desired area, multiplication of cropped image with the enhanced version of the difference image is carried out. Traffic density in the desired area is calculated in the next step. For that, vehicles are marked and counted. The algorithm searches for a set of connecting pixels. A minimum threshold has been defined, in order to consider a connected region as a vehicle. However, it is possible that more than one region of the vehicle is detected using the above criteria. The problem could be overcome by finding the overlapping boundary boxes of the selected regions and these smaller and highly overlapping regions are filtered out.

K. Vidhya and A. Bazila Banu [3] implemented another method for traffic control based on density analysis. Initially, the captured RGB image is converted into grayscale image which is then converted into threshold image. Thresholding can be used to create binary images from the grayscale image. Now the threshold image is converted into the Canny image using Canny edge detection method [9]. This method can be used to outline the edge of the objects, which will help to find the vehicles in the image. Erode image [3] is similar to canny image but it finds the edges with darker lines. Next, erode image is converted into contour image [3] to find vehicle count in that image. There are two types of output screens displayed in this system:

1. The first screen displays the RGB image where vehicles are represented within boxes
2. Second output screen is a command prompt which will be opened when the user runs this system and the count of vehicles present will be displayed on it.

They used OpenCV tool as software for image processing by just displaying various conversions of the image on the screen and finally surrounding the box on the vehicle in the given image. The number of vehicles present is calculated and based on that traffic signal is controlled [3].

Pallavi et al. [4] proposed another method for traffic monitoring which includes three main phases. In the first phase, the reference image is captured. This RGB image is then converted into the grayscale image. Now gamma correction [4] is done on the grayscale image to achieve image enhancement. Further, Prewitt edge [4] detection algorithm was used to detect the edges. In the second phase, same operations of phase I are performed on the image with traffic. In the third phase, the reference image and image with traffic are matched. In image matching, each and every edge in the reference image is compared with every edge in the traffic images. And based on its result, traffic signal controlling is done. Using the percentage of matching of traffic image with reference image, traffic light signals are controlled as follows:

- 0-10% matching: green on for 90 seconds
- 10-50% matching: green on for 60 seconds
- 50-70% matching: green on for 30 seconds
- 70-90% matching: green on for 90 seconds
- 90-100% matching: red on for 60 seconds [4]

P. Sreenivas et al. [5] implemented another method for real-time traffic monitoring. Different steps involved in this work are image capturing, background subtraction, edge detection, object counting and traffic regulations. Images captured from the video are then analyzed to detect and count vehicles. The proposed system checks for any emergency vehicle. If found any, then that lane is given priority over all others. In background subtraction, the technique is based on computing the error between a constant background frame and the current one. Generating the current background image is based on segmentation results, where segmentation results are extracted from differencing the image with the previous extracted background. This is the basic idea of their method. The updated background (Bnew) is computed as a function of current background (Bo) and current frame I through the equation given below.

$$B_{new} = \begin{Bmatrix} (\alpha * Bo) + (1 - \alpha) * I if RES = 0 \\ Bo, otherwise \end{Bmatrix}$$

Where RES is the result of subtraction of consecutive frames, and the value of α is 0.5. In this paper, they tried out most of the edge detection techniques and found canny edge detection as best among those techniques (93.47%). After finding the edges, the next stage is to count the number of objects as defined by the edges. For this, they used Moore-Neighborhood algorithm [10]. The contour tracing algorithm enables to define the boundary of the objects as well as their size.

III. MATERIALS AND METHODS

A. Steps in Automatic Traffic Control

There exists five phases in Automatic Traffic Control System with Real Time Vehicle Density Analysis and these steps are represented diagrammatically in figure 1.

Image acquisition: It is the process of capturing the image of the road, under preview. Camera are to be fixed at an elevated positions so as to perform the image acquisition. These real-time traffic images are analysed, using image processing techniques, to find the density of the roads under consideration. [7]

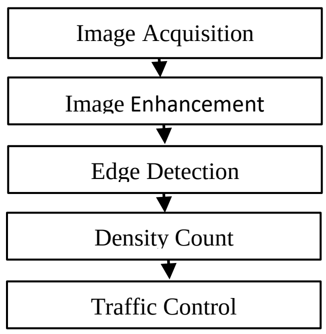

Figure 1 Block Diagram of the proposed work

Image enhancement: Here in the image enhancement phase, the raw images are captured, cleansed and manipulated according to our requirements, so that the result is more befitting than the original, for the real time vehicle density analysis. Various image enhancement schemes employed are: RGB to grayscale conversion, gamma corrections to remove noise, image cropping to remove unnecessary information etc. [8]

Edge detection: Here in this phase, edges or boundaries of any object present in the image are identified by detecting discontinuities in brightness. The common edge detection techniques popular among research communities include Sobel, Canny, Prewitt, Roberts, and fuzzy logic methods. Here in the preview of this study, Canny Edge detection mechanism is used. By finding certain connected edges, the algorithm can detect the presence of vehicle on each road. [6]

Density Count: Density of vehicles are found out separately, for each road under preview, to make intelligent decision on how much time one need to allocate for a given traffic. Introduction of density analysis brings dynamism to the automatic traffic controlling system thus enhancing the overall performance of the system.

Traffic controlling: This is the most crucial part of the study where signals are passed on to glow the red, green and the yellow lights. These decisions are derived by dynamically analysing the density count present in each road. If a road reports higher density over others, then that road should be given higher privilege. In other words, higher the density value, higher the time period of that signal light will be. While incorporating density analysis, there exist a probability of certain roads getting consecutive time quantum which in turn may starve other roads from getting their share of priority. This problem of starvation is resolved by setting certain priority values for each road. These value of road were set to zero upfront and are incremented/ decremented based on time allocation. Time allocation for green signal, based on the density count of vehicles present, is as follows:

- When density of vehicles > 10 then permit traffic for 30 seconds
- When density lies between 6 to 9 then permit traffic for 20 seconds
- When density lies between 3 to 5 then permit traffic for 15 seconds
- When density of vehicles is 1 or 2 then permit traffic for 10 seconds

Once density of each roads are analysed and traffic flow is granted, using the above mentioned algorithm, one need to regulate traffic flow from one road to another and the algorithm which does it is illustrated below. Initially the priority value of each road is set to zero.

Step 1: Start

Step 2: All roads are given RED signal

Step 3: if any roads have priority >=3

a, if multiple roads have priority >= 3

I, if those roads have same traffic density,

Then, arbitrarily select any road and grant GREEN signal

II, Else,

Among those roads, GREEN signal for road with highest traffic density

b, else grant GREEN signal for road with highest priority

Step 4: Else find roads with highest traffic density with priority greater than or equal to 0

a, if more than one road have same traffic density

i, if these roads have same priority value,

then, arbitrarily select any road to grant GREEN signal

ii, else, GREEN signal for road with highest priority value

b, else grant GREEN signal for road with highest traffic density

Step 5: Priority of road with GREEN signal is set to -1

Step 6: Priority of road with RED signal is incremented by 1

Step 7: Repeat steps 2 to 6 until the system halt.

B. Development of a Prototype

Hardware part:

With the below mentioned hardware devices, a prototype was developed for easy implementation and through understanding of the proposed system.

- Arduino mega 2560 board
- Webcams with minimal resolution of 1280 x 720
- Servo motor (Airplane 9g Mini Servo - SG-90)
- Led lights
- Laptop (Core i3 processor, 4 GB RAM)

Software part:

- Operating System: Windows or Linux
- Matlab R2015b
- Photoshop CS

As depicted in figure 2, the prototype includes a traffic junction with four roads and signal lights for controlling the flow of traffic in it. Two webcams are fixed on a servo motor which was placed on a higher position in a traffic junction. Servo motor was introduced to resolve the technical difficulties encountered while connecting four webcams simultaneously. First, images of two roads are captured and then the cameras are rotated 90 degrees, using servo motor, to capture the other two. While initialising the system, images of four roads are captured using the webcams and required region in each roads are marked white and the unwanted regions are marked as black, as shown in figure 3 and figure 4. This process will help the system to identify vehicles which lies in the ambit of our study. These images are marked as reference image of respective roads and are captured once.

Matlab 2015b is used for developing the software part of the system. An Arduino mega 2560 board is used for controlling the signal lights (led's in this prototype). The Arduino board was programmed using Arduino software to assign the various input pins. The values derived from the Arduino board are then controlled using Matlab software.

Figure 2 Prototype

Figure 3 Traffic image

Figure 4 Reference image

C. Implementation of Automatic Traffic Control System

Images of the roads under preview are captured in RGB format and are converted into grayscale images. Further these grey scale images are converted into binary images using Otsu algorithm. After performing the necessary image enhancements, edge detection operation is performed over the binary image. Edges - a curve that follows a path of rapid change in image intensity, are extracted by Canny edge detection algorithm and from these details conclusions are derived over how many vehicles exist in a particular area. Once through, some more enhancement operations viz. image dilation, image fill, and removal of unwanted objects or areas, are done on the canny image.

After these image enhancement operations, the number of vehicles present on each road is determined which is based on its region properties. Region properties are measures that portrays the properties of the image regions under consideration and are predefined as a function in Matlab. Once initiated, Regionprops will return the measurements of an array of properties for each 8-connected component in the binary image. After identifying the vehicles, corresponding portions are marked with bounding boxes. By counting all bounding boxes present, the algorithm can correctly predict the actual density count of vehicles. Figure 5 and figure 6 shows the initial captured traffic image and its corresponding traffic density represented as bounding boxes.

Once details of the uplink is computed, webcams are rotated 90 degree, using servo motor, and the same procedures are performed on the downlink to find its vehicle densities.

After finding out vehicle densities of each road, decisions are to be drawn about the roads that should have the traffic permission. These decisions are primarily drawn based on the vehicle density and traffic lights are lit accordingly. This algorithm is designed to eliminate all drawbacks what were listed in the previous sections. For example, the problem of a road having traffic permission where the traffic density is minimal / nil can be solved with the implementation of this algorithm. Further, the amount of time one gets solely depends on the traffic and hence the problem stated is resolved.

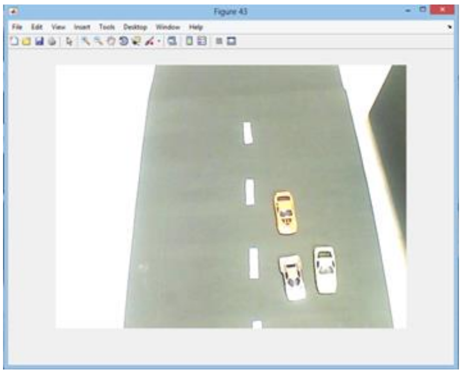

Figure 5 Traffic image

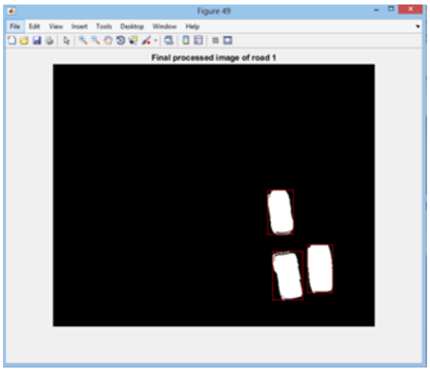

Figure 6 Final processed image

IV. Conclusions and Future Directions

In the contemporary society, traffic is increasing exponentially and so does the traffic congestion. To curb this menace, a novel traffic controlling system, with minimal human intervention, is to be introduced. By proposing density analysis to existing traffic controlling system, authors were able to predict that the efficiency of the system can be enhanced substantially. These hypothesis was proved by developing a prototype using Arduino mega 2560 board, Webcams and Airplane 9g Mini Servo - SG-90 and led lights. The system was developed successfully and while evaluating it, it was observed that many of the drawback, reported by the literature, were eliminated or minimized.

As a future enhancement, authors propose to give special consideration to certain vehicles viz. ambulance, fire engine, vehicles of policemen and statesmen. One need to develop algorithms to detect emergency vehicle on these lanes and priorities are to be recomputed thus assigning special privilege to these lanes.

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