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Automatic Traffic Light Control System using Digital Image Processing and Ambulance Detection using Radio Frequency Sensors

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Abstract: *Traffic is one of the major issues in India. The population explosion has led to extreme growth in traffic all over India, especially in the major cities, which leads to wastage of fuel and time, waiting at signals. Most signals have preset values for timers. Traffic in India being very unpredictable, and haphazard using preset timers is not the most efficient way to control traffic flow at signals. One of the best methods to control traffic lights, is calculate the traffic density on the roads using Image [2] videos captures in real time, and actuate the lights based on the latest traffic densities calculated using Image Processing. This project discusses on how to control traffic at a four-road junction, efficiently. In India, most cities do not have dedicated lanes for ambulances use, owing to high traffic everywhere. If an ambulance is stuck at a signal waiting for eternity, can cause loss of life. Detecting presence of ambulance on roads at signals has become ever more imperative [8]. RF modules is the answer, to detect the presence of an ambulance at the earliest and make sure it is on its way [6]. Closed Circuit Cameras are used to capture the videos at the junction.*

Key Words: **Contour Analysis, Traffic Flow Control, OpenCV, MySQL Database, Gamma Filter, Raspberry Pi, Arduino**

1.INTRODUCTION

Traffic is a major impediment in most metro cities in India. Owing to the population explosion that India is facing traffic control is a must needed solution. It not only wastes time, but also wastes precious fossil fuels which is used by more than 90% of vehicles, which are almost always stuck in traffic either due to extremely small roads or because the number of vehicles on road are increasing at an alarming rate [2][9]. There is always a possibility that some of those vehicles stuck in traffic are ambulances, which is cause for major concern. India due to the number of vehicles that are always on the rise, having reserved lanes for Ambulances is just not practical in most cities.

Presently in India most of the sluggish traffic happens to be at signals especially the larger junction where 3 or more roads meet. The signals right now only use preset timers for each signal. Though this may work, considering that traffic is ever increasing, this is not an efficient scheme to control the traffic flow at a junction. There always is a situation where one of the roads has very less traffic and the other road might have extremely high traffic but is stuck with a red light since the road with lesser traffic has green light and is jammed that way until the timer runs out. This is very inefficient.

There is an alternative that has been explored. The timers on each road will be set based on the time of the day. For e.g. Road A might have high traffic in the morning but have a lot less in the evening, whereas it is vice-versa for Road B. So, in the morning time, Road A has more time set for it, and in the evening time Road B has more time set. Yet again this approach has also become inefficient because of the haphazard nature of traffic. Irrespective of the time, traffic happens to always be unpredictable on any road.

The next solution is to determine traffic density of each road on a junction in real time [9] and give green lights such that the road with the highest traffic is given green light first, and then the other roads are given green lights in accordance with their latest traffic densities. The very popular solution to this is Image Processing [2].

An important feature to have, whatever might the solution might be is to have a subsystem to detect ambulances. As stated, earlier ambulances, just as other vehicles might be also be stuck at a signal waiting for its turn, which can have dire consequences for the patient it may be carrying, during the wait [8]. The ambulance must be allowed to leave as early as possible.

1.1 Methodology

Study & Selection Phase

- Decide on requirements for the project
- Evaluate and choose a suitable microcontroller for the project
- Evaluate and choose a suitable method for calculating traffic density.

Architecture & Design Phase

- Design the algorithm for calculating traffic density.

- Adjust the various masks to successfully mask all other colors other than the road.

Implementation Phase

- Develop the program for the selected microcontroller.
- Integrate all components with the microcontroller to build the final device.

System Testing Phase

- Testing the device built under various test conditions.

Field Testing & Deployment Phase

- Make any needed changes if required and then validate the prototype system framework.

1.2 Procedure

Phase 1:

- The four videos are captured from four cameras
- Finding the region of interest and denoising is performed
- Gamma correction is performed for all four videos to achieve image enhancement
- Dilation is performed for a colour image
- Conversion of RGB to HSV
- Masking is performed for each HSV sample
- Image subtraction
- RGB to GRAY conversion
- Canny edge detection and contour analysis
- Finding the area of all contours, which is the traffic density.
- Updating the traffic densities to MySQL database.

Phase 2:

- Checking for ambulance presence
- If ambulance is detected on a road, say Road X, Road X is immediately green lit, to let it pass.
- If no ambulance found, the road with highest traffic density is retrieved from database, say Road Y
- Main timer is started.
- Road Y is given the green till it is empty.

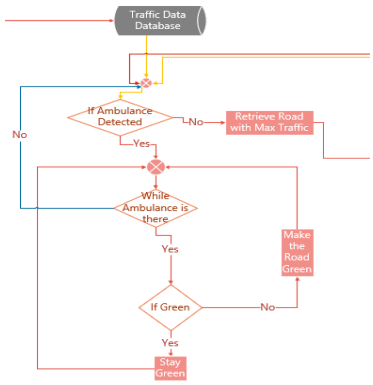

Figure 1: Ambulance Detection

Phase 3:

- If traffic on Road Y does not decrease, Main timer runs out.
- The control goes to the road with 2nd highest traffic density, for a fixed period.
- Control returns to the road with highest traffic density.
- This repeats with road with 3rd and 4th highest traffic densities every time the main timer is overrun.

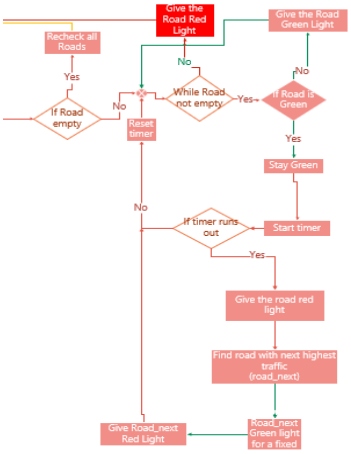

Figure 2: Traffic Control

2. SOFTWARE

Python 3.7

The majority of the system was designed in Python. Python is a general purpose, interpreted, object oriented, high level programming language. Owing to its simple programming syntax, code readability python was chosen as the preferred language for the system to be programmed. The other factor to be considered it that, it has an abundance of prebuilt modules and packages that make it easier to program.

It can also be used to interact with remote databases either for Data Retrieval, or Data Manipulation.

Arduino IDE
Arduino IDE is an Integrated Development Environment for programming on Arduino Boards, which makes it easy to write code and upload code to the board. The environment is written in Java and is based on Processing and other open source software.

MySQL Workbench
MySQL is an open source relational database management system. SQL is short for "Structured Query Language"

3. HARDWARE

Raspberry Pi
Raspberry Pi is a cheap single board computer, used for building hardware projects, home automation (i.e. Iot Applications) or used even in industrial applications. It is the ideal processor to perform applications involving Image Processing, since it has dedicated port to connect to a camera.

It also has 40 GPIO pins for controlling other kinds of hardware, which also includes pins for UART and SPI.

Arduino Uno
Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator a USB connection, a power jack, an ICSP header and a reset button.

RF Modules
This includes the RF transmitter and Receiver Module. They operate over the frequency of 315MHz. Both the transmitter and receiver tune into the same Radio Frequency, so that when the transmitter transmits a signal the receiver will hear it wirelessly [6]. The particular model used is XY-MK-5V.
The receiver has an input voltage of 5V.
The transmitter can operate between 3.5V to 12V. The range is directly proportional to the input voltage. The maximum operating distance is 200m.

4. EVALUATION AND RESULTS

Step 1: Basic Manipulation – Region of interest
Region of interest is obtained using Cropping technique. This helps views focus on particular portion of an image and ignoring the leftover parts. Non – local means denoising is done. Figure (3) shows the original image after performing cropping.


Figure 3: Original Frame

Step 2: Image Enhancement – Gamma / power – law transformations
$$O = C \bullet I^{\gamma}$$
The above expression shows the power – law transformation where I can be called as input image, O can be assumed as the output image, C is termed as a constant value and γ is called gamma. Variation of γ varies the enhancement of the images. This function points luminance values to assure the non-linear luminance values of the devices [2]. We have taken $\gamma = 2$. This value makes shadows darker and darkens the road. In this way vehicles such as bikes and bicycles can be highlighted. Figure (4) shows the denoising and gamma corrected frame.

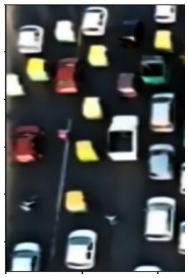
Figure 4: Enhanced Frame

Step 3: Image Morphology – Dilation
This technique increases an image region. We have taken a structured element(kernel) of 3×3 size and performed four iterations. We have performed dilation for a colored image [1]. The structured element is used to probe the input image. In this way the boundary of foreground objects(vehicles) is increased and thus helps in identifying the objects for feature extraction. Figure (5) depicts the dilated frame.

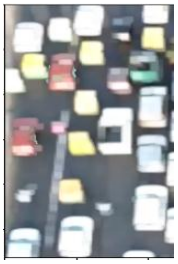
Figure 5: Dilated Frame

Step 4: Feature Extraction – Masking

This method highlights the specific object in an image by masking it. In order to identify a specific object, a mask is designed which has same properties of the object to be identified. In order to perform masking, we have to change the image space from RGB to HSV color space, since this technique is easier and faster way to isolate colors. We have designed a mask which has same properties as road color pixels. The below Figure (6) shows the masked frame

Figure 6: Masked Frame

Step 5: Image Segmentation – Edge detection and Contour analysis

Canny edge detection that works on an algorithm consists of multiple stages to identify huge range of edges in an image. This method reduces false edges and is best in noise reduction [3]. RGB to gray conversion is performed. Figure (7) depicts the edge detection.

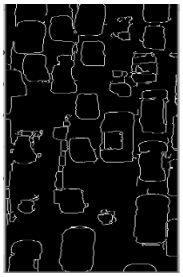

Figure 7: Edge Detection

Contour analysis: This technique is performed on a binary image which is the resultant of canny edge detection [7]. This operation is performed to find the area of each vehicle which in turn gives the traffic density for each road in a junction. Figure (8) gives the contour for each vehicle which in turn finds the area of each contour.

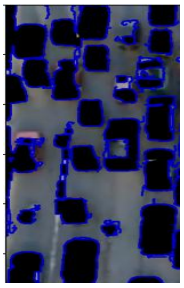

Figure 8: Contour analysis

5. SETUP

In order to prove the functionality, 2 Raspberry Pi microcontrollers, 2 Arduino microcontrollers have been used.

The assumption is that, each ambulance is fitted with a RF transmitter. The signal at each road is fitted with a receiver, which have sufficient separation such that no interference occurs.

There is a CCTV camera facing each road. Each camera is capturing a video, which is processed frame by frame to extract traffic densities on each road. (Only 2 cameras are being used in here for demonstration due unavailability of extra cameras). Raspberry Pi cameras are being used in place of CCTV cameras for demonstration. Figure (9) depicts the circuit diagram which does not contain cameras and 2nd raspberry pi. Figure (10) depicts the hardware setup to find the traffic density and controlling the traffic lights.

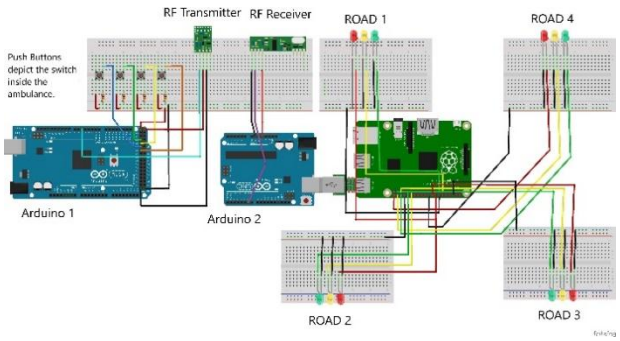

Figure 9: Circuit Diagram (Cameras and 2nd Pi not depicted)

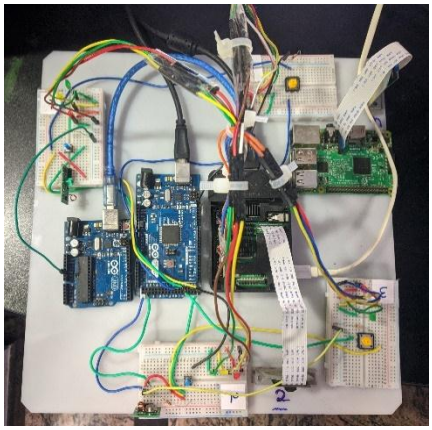

Figure 10: Setup

6. CONCLUSIONS

This paper talks about how traffic flow can be controlled efficiently, through the method of Digital Image Processing. Our results demonstrate that traffic can be successfully controlled using the image processing approach and proves that it can minimize the waiting times for vehicles at signals. The paper also talks about the importance of Ambulance Detection, specifically in India. It validates that the presence of an Ambulance can be ascertained using the technology of RF (i.e. Radio Frequency) Communication, and also to give them the priority only in a case of incidence, not superfluously.

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BIOGRAPHIES:

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