Smart Traffic Management System Using Digital Image Processing and Internet of Things

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Abstract- *Due to the ever increasing population, the problem of traffic congestion is not a new one in the urban scenario. Increasing number of vehicles will lead of a lot of problems such a major traffic congestion, increasing pollution levels and health problems to name a few. The problem of traffic congestion however, can be solved using a smart traffic management system. The system that we propose uses Digital Image Processing along with IOT to help reduce the traffic congestion at signals. The camera present at the signal captures the traffic at regular intervals. Using Digital Image Processing, the density of vehicles at every signal in the junction is calculated. According to the density at each signal, the time for the green signal is allocated, i.e., the signal with the highest density of gets green signal for a longer period of time . IOT and Zigbee communication is used to warn the other signals to divert the traffic away in case of an accident or congestion between signals. Digital Image Processing and IOT communication will ensure a faster and a more effective way of traffic management.*

Keywords- Digital Image Processing, Smart Traffic Management, Signal-to-signal Communication, , Traffic Congestion

I. INTRODUCTION

IOT is an innovation which uses internet to control the physical items.IOT can be used to get an outcome which is more precise, quick and exact. The computer stores all database in IOT. This storage is done through internet. Later this database is used accordingly to their requirements and applications. IOT accesses components from far place, hence reducing human work or involvement. This makes investment of system less. All different protocols are used in respective domains of IOT accordingly. Digital image processing is another paradigm which helps process the images using computer algorithms. Combining these two technologies result in an efficient technique to manage traffic problems.

Most of the countries face problem in traffic congestion and this needs a solution. Traffic Congestion is a major issue. Because of this problem, time taken for travelling will be increased. If we can design a control system for traffic in proper way this congestion problem would be solved. Hence by using IOT and digital image processing concepts this can be solved. If traffic lights work depending upon the vehicle number in a lane/road, then time management for traffic lights can be done easily and congestion could be reduced in great way. Providing Green signal to emergency vehicles is an important task to save a patient's life. This also includes a signal to signal communication, wherein a signal would give its status to all the nearby signals.

The creation of smart/adaptive traffic signals aims at solving long time existent problems like traffic congestion. It allocates the signal timings based on the traffic densities, hence providing lesser wait time for lanes with higher traffic density, and proving sufficient time for vehicles in lanes with less density. It also reduces the manual works which have to be done by the traffic police, such as adjusting the signal timings for the varying traffic. The emergency clearance assures ambulances reach hospitals on time without facing any traffic problems. The rerouting system gives an alternate route at the previous junctions in case of a heavy congestion or an accident.

II. DESIGN

A. Architectural Design

The flow of information of any process of a system as be mapped using an Architectural Design.Data flowcharts can range from simple, even hand-drawn process overviews, to in-depth, multi-level DFDs that dig progressively deeper into how the data is handled.

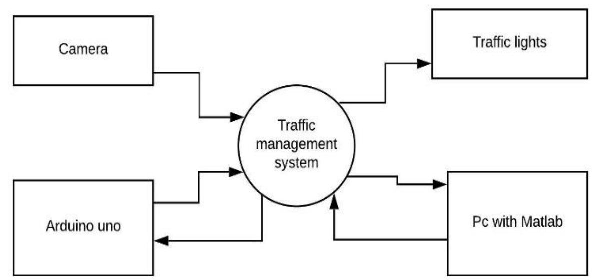

Fig. 1. Architectural design for Smart Traffic Management

The above fig.1shows the DFD 0 for smart traffic management system. The above diagram has 4 entities; the camera connected to Arduino UNO which is in turn connected to a PC with Matlab. And the Arduino board is connected to the traffic lights.

B. Component Design

Component design maps out the flow of information for any process or system. It gives a more detailed view of all the data interactions between the systems.

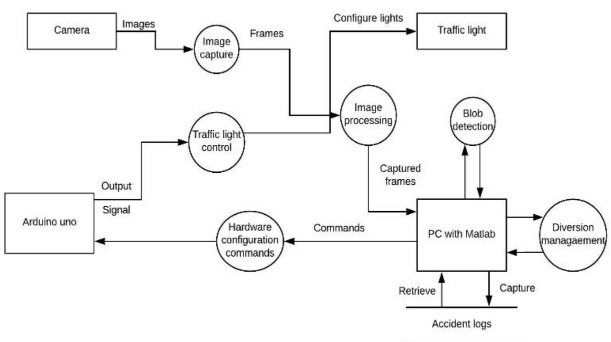

Fig. 2. Component design for Smart Traffic Management

The above fig. 2 shows the DFD 1 for smart traffic management system. This figure shows the processes that are running between entities in a detailed way. The camera records images which are then processed in the Matlab and after the image frames are processed, respective commands are sent to the Arduino board. The Arduino board, based on these commands in turn controls the traffic signals.

III. IMPLEMTATION

The digital image processing is a main component of the smart traffic management system and contributes to the majority of the implementation. Digital image processing methods are mainly used for two principal area of application, improvement of pictorial information for human interpretationand with respect to processing of image data for storage purposes, transmission, and representation for autonomous machine perception.

An image may be defined as a two-dimensional function, f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of function f at any pair of coordinates (x, y) are the intensity or gray level of the image at that point .When x, y, and the amplitudeof f are all finite and discrete quantities, we call the image a digital image. The field of digital image processing refers to processing ofdigital images by the means of a digital computer. These elements are called as picture elements, image elements, and pixels. Pixel is the term which is most widely used to denote the elements of a digital image.

In order to become suitable to digitally process it, an image function of f(x,y) must be digitized both spatially and in amplitude. Typically, a frame grabber or a digitizer is used to sample and quantize the analogue video signal. Hence in order to create a digital imagewe need to covert continuous data into digital form. The below are a series of steps that will be used to achieve an optimal digital image.

A. Image Acquisition

Before any processing of video or image can commence, an image must be captured by a camera and converted into a manageable entity. This is the process known as image acquisition. The image acquisition procedure consists of three steps; energy that is reflected from the object of interest, an optical system which concentrates the energy and finally a sensor that measures the amount of energy. In order to capture an image a camera requires some sort of measurable energy. The energy of interest in this very context is the light or more aptly electromagnetic waves.

In this project video is captured and that video is converted into frames to be processed.Video captured is analog and it is captured live from the road or any place with moving object. Video signals those are taken by camera are converted into digital format and then it is stored in storage device. Video captures from analog devices require a special video capturing card that converts the analog signals to digital form and compresses the data.

B. Image Re-sizing/Scaling

Image scaling occurs in almost all digital photos at some stage. It happens everytime you resize your image from one pixel grid to another one. Image resizing is a necessity when you need to increase or decrease the total number of pixels. Even if the same image resize is done, the result can vary significantly depending on the algorithm. It plays one of the important role in increasing the processing speed. Images can be resized because of number of reasons but this is one of the important reasons in our project. Every camera has its own distinct resolution, so when a system is designed for certain camera specifications it will not run appropriately for any other camera depending on its specification similarities. So, it is necessary to make the resolution constant for the application to perform resizing.

Image scaling in our project has been done in terms of its resolution. The resolution can be enunciated in many ways such as pixel resolution, spatial resolution, temporal resolution, spectral resolution. Out of these, we are going to discuss about pixel resolution. The total number of count of pixels in a digital image is referred as resolution in pixel resolution. An image with M rows and N columns, can be defined as M x N.

If we define resolution as the total number of pixels, then pixel resolutions are defined with set of two numbers. The first number is the width of the picture or the pixels across columns, and the second number is height of the picture, or the pixels across its width. We can say that higher the pixel resolution, the higher quality of the image.

C. RGB To Gray Conversion

Humans perceive colour through wavelength-sensitive sensory cells called cones. There are three vivid varieties of cones, each with different sensitivity to electromagnetic radiation (light) of different wavelength. One cone is only sensitive to green light, similarly one to red or to blue light. By emitting a restricted combination of these three colours (red, green and blue), and hence stimulating the three types of cones at will, we are able to create and detect any colour. This is why colour images are often stored as three separate image matrices; one storing the amount of red (R) in each pixel, one the amount of green (G) and one the amount of blue (B).

In grayscale images we do not differentiate how much different colors are emitted, we emit the same amount in every channel. We can differentiate the total amount of emitted light for each pixel and little light gives dark pixels and much light is perceived as bright pixels.

Fig. 3. RGB image and grayscale image

When converting an RGB image to grayscale, we've to think about the RGB values for every pixel and make the output one value reflecting the brightness of that pixel. One among the approaches is to take contributions from each channel: (R+B+C)/3. However, since the perceived brightness is usually dominated by the green component, a special , more "human-oriented", method is to think about a weighted average, e.g.: 0.3R + 0.59G + 0.11B.

Gray levels represent the number of quantization in gray scale image processing. At the present , the foremost commonly used storage method is 8-bit storage. There are 256 gray levels in an 8 bit gray scale image, and therefore the intensity of every pixel can have from 0 to 255, with 0 being black and 255 being white.

D. Image Enhancement

The main goal of image enhancement to improve the visibility and perceptibility of the various regions into which an image can be partitioned and the detecting ability of the image features inside these regions. Image enhancement includes: cleaning of various kinds of noise from the image; enhancing the contrast of the objects and surroundings; simplifying the image via selective smoothing or elimination eliminating the unwanted parts of the image. Image enhancement is optionally followed by edge detection to eliminate regions of low interest.

Enhancement can be accomplished by - Noise suppression, Simplification by retaining objects of interest, Contrast sharpening. The first two can be viewed as part of image smoothing. The below image Fig. 4 shows quality of the image post image enhancement.

Fig. 4. Image enhancement

Traditional approaches of solving the above tasks have primarily used the linear systems, however nowadays a new understanding has matured that linear approaches are not well suitable or sometimes fail to solve problems involving geometrical aspects of the image. Hence nonlinear geometric approaches are more commonly preferred now. A powerful nonlinear methodology that can address the above limitation of linear approach is the mathematical morphology.

Mathematical morphology is a set and lattice-theoretic methodology for image analysis, which aims at quantitatively describing the geometrical structure of image objects. The above evolution of ideas has formed what we call nowadays the field of morphological image processing, which is a broad and coherent collection of theoretical concepts, nonlinear filters, design methodologies, and applications systems.

E. Background Subtraction

Background subtraction, also referred to as Foreground Detection, is a technique within the fields of image processing and computer vision. The main objective here is to extracted an image's foreground for further processing. A foreground is basically the region of interest. Here in our project the foreground would be the traffic density. Background subtraction is the most commonly used approach to detect moving objects in videos from a static camera.

The idea in this approach is to detect the moving objects from the difference between the current frame and a reference frame, also called "background image", or "background model". However, background subtraction is often based on an assumption that the background is static which might not be applicable in real environments. Sometimes reflections or animated images on screens lead to background changes which might affect the background subtraction with indoor scenarios. In a same way, wind, rain or illumination changes due to the weather, can significantly affect static backgrounds with outdoor scenes.

A motion detection algorithm begins with the segmentation part where foreground or moving objects are extracted from the background. The simplest way to implement this is to take a sample background image and then take the frames obtained at the time t, denoted by I(t). Then compare the frames with the background image denoted by B. Here using simple arithmetic calculations, we can extract the objects of interest using image subtraction technique. Assuming each pixels as I(t), the pixel value as P[I(t)] and subtracting it with the corresponding pixels at the same position on the background image P[B]. To represent this in a mathematical form we use the equation, $P[F(t)] = P[I(t)] - P[B]$.

The background image is considered to be the frame at time t. The change in the pixel intensity in some locations of the two frames show the difference of the frame with the background image. Though we have seemingly removed the background, this approach will only work only in cases where the background images are static and the foreground pixels are moving. A threshold put on this difference will improve the image subtraction.

In our model, the background image is the image of the traffic junction with no vehicles. The images captured at a time t, which has some objects of interest in the foreground i.e vehicles is then subtracted with the background image. The difference in pixel intensities between these two frames are the objects of our interests in the foreground. The subtracted image can now be used for calculating the densities.

IV. ALGORITHM FOR TRAFFIC SIGNAL ALLOCATION

The simplified algorithm for Traffic Control using Arduino Uno is as below,

Step 1: Initialising the lanes (1, 2, 3, and 4) to their respective pins of Arduino.
Step 2: Declare all the lanes as output lanes.
Step 3: Initially set all the lanes in off condition (red).
Step 4: Make L1 high(Green) and all other lanes as low(Red).
Step 5: Introduce delay for some duration.
Step 6: Change L1 and L3 to yellow and L2 and L4 to red.
Step 7: Introduce delay for some duration.
Step 8: Change L3 to green and all other lanes to red.
Step 9: Introducing delay for some time.
Step 10: Changing L2 and L3 to yellow and other lanes to red.
Step 11: Introducing delay for some time.
Step 12: Changing L2 to green and all other lanes to red.
Step 13: Repeat the above steps for other lanes and so on

V. RESULTS AND SNAPSHOTS

To simulate the conditions of the actual environment we have modeled a four way traffic junction. The traffic density is scattered across the four sides of the junction to emulate the variable traffic density scenario.

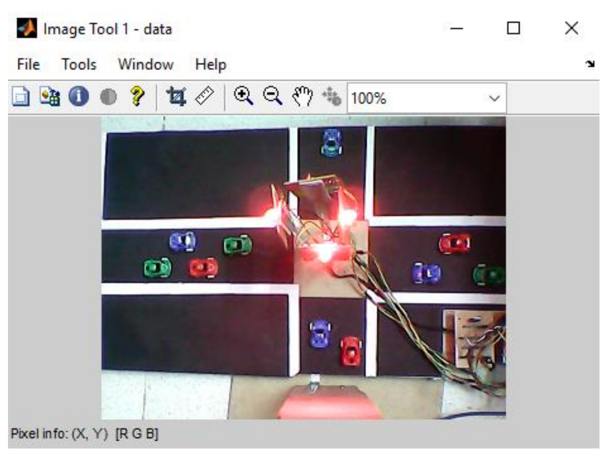

Fig. 5. Setup of four way traffic junction

The signal initially operates at the standard timings provided. Once it receives some information through the Arduino it changes accordingly.It has a red, yellow and green LED all connected to the Arduino. During its normal function the red, yellow and green have all been set to a standard time for all the 4 sides of the junction. Once the image has been processed the 4 signals are set according to the results of the image processing.

Fig. 6. Color detection though MATLAB

Fig.5 is the image of initial set up in the MATLAB. Initially once the camera is set, we need to mark the coordinates of the roads, so that vehicles in that road coordinates can be captured and density can be calculated. Fig. 6 is the image in which the MATLAB has detected the vehicles. The vehicles are marked with a box along with the color of the vehicles.

Post identifying the vehicles on each side of the traffic junction, we subtract the image with the background image. The background image here is the image of the traffic junction without the vehicles. At this we arrive at the traffic density on each side of the traffic junction.

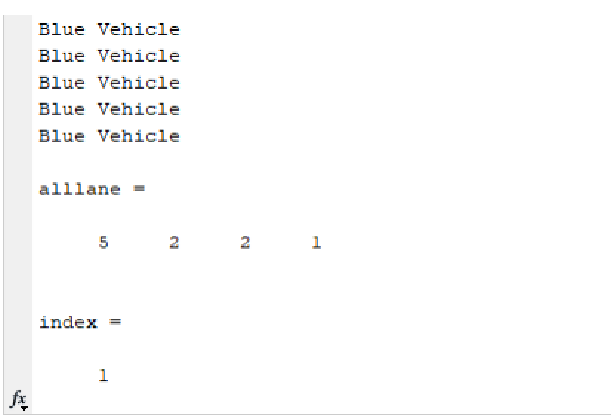

Fig. 7. Detecting the density of traffic

Fig. 7 is from the output window of the MATLAB. It gives the density of vehicles on each side of the junction. It also gives us the information regarding which junction has the highest traffic density. Here the lane with highest traffic density is at index 1 with a traffic density of 5. Hence this lane would require more time than the other lanes. Once these densities are calculated the algorithm is applied, and the output is fed into the Arduino. The Arduino then drive the traffic LED's based on the output of the algorithm. Now the traffic timings are dynamically adjusted based on the density on each side of the traffic junction. This process continues till interrupted or terminated.

VI. CONCLUSION AND FURTHER ENHANCEMENTS

The main purpose of this project is to help build better and smart cities. With density based traffic lights people save a lot of time in signals. They can be on time wherever they need to be without any traffic congestions. The rerouting system helps to take a different route on heavy congestion or an incident at a junction. This again helps people to save their time and avoid congestions. It also helps the site of incident safe from traffic congestions thereby giving a safe channel for the ambulances. The emergency vehicle clearance helps to clear the signal at which an emergency vehicle is arriving thereby giving a safe passage to the emergency vehicles. This ensures that they reach on time without any causality. Thus this project is a complete solution to control and manage traffic thereby helping the people to have better lives.

Future enhancements for this project are - an enhanced 360 degree camera to monitor all the junctions at a time, efficient algorithm to detect vehicle density, efficient emergency vehicle detection with digital image processing, establishing signal to signal communication to allow interactions between traffic signals.

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