Journal of Engineering and Applied Sciences 12 (22): 6076-6082, 2017
ISSN: 1816-949X

Smart Traffic Signal by Digital Image Processing using PCA Algorithm and Edge Detection Techniques

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Abstract: Urban traffic is an ever-growing issue in major metropolitan cities and despite advancements in automotive engineering, traffic signals all over the world have not adapted to the times. In this study, implementation of a smart traffic signal on MATLAB using digital image processing is proposed. The procedure mainly consists of four steps: image acquisition, RGB to gray conversion, image enhancement and image matching using edge detection. This process would require a constant live-feed CCTV image of the traffic at a particular intersection as a prerequisite, this image will continuously be compared with preset images and compared. Accordingly, the duration the signal remains on or off can be determined based on the similarities of the two images.

Key words: MATLAB, ITS, image database, image processing, edge detection, PCA

INTRODUCTION

As more and more cars keep jamming streets and increasing travel times due to traffic, traffic surveillance has become a crucial tool to regulate its flow. Giant leaps in technology have enabled cars to travel faster and be more efficient, however the technology used in a traditional traffic signal is simply a timer and needs to be updated.

We look at the current traffic systems, how they are implemented along with its positives and negatives. Edge detection is the concept used to detect the images in digital image processing in the initial/pre-processing phase of the image. There is a certain procedure that needs to be used to transform the acquired image to one which is eligible to be compared by the algorithm:

The image is first filtered to "RGB to Gray conversion", this changes the regular image to an image consisting of varying shades of grey. Then the image is re-sized and enhanced, after this edge detection takes place, principle component analysis is used for image matching and finally there is an allocated time that needs to be set with each image.

In the purview of Internet of Things (IoT), Intelligent Transportation System (ITS) is an emerging technology and there is extensive research conducted to help manage traffic. Sensors have been employed to estimate traffic parameters for updating traffic information. Magnetic loop detectors have been the most used technologies but their installation and maintenance are inconvenient and since ITS is making great strides continuously, there is a chance that this might become incompatible with future ITS technologies and infrastructure (Choudekar *et al*., 2011). It is widely known that vision based camera systems are more adaptable for estimating parameters and severity of traffic.

Limitations of existing system

Heavy traffic jams: With increasing number of vehicles on road, heavy traffic congestion has substantially increased in major cities. This happened usually at the main junctions commonly in the morning, before office hour and in the evening, after office hours. The main effect of this matter is increased time wasting of the people on the road.

No traffic but still need to wait: At certain junctions, sometimes even if there is no traffic, people have to wait. Because the traffic light remains red for the preset time period, the road users should wait until the light turn to green. If they run the red to avoid the above mentioned limitations, the study implements feedback based traffic management system. The main emphasis is given to control traffic in minimum amount of time and building an efficient solution for traffic jams. This study proposes using live feeds from surveillance/CCTV cameras to get continuous real time images of the junction in question and compare these images with pre-existing images which are set using certain criteria.

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There will be certain outlines that control the duration of the signal being green; distinguishing the presence or absence of vehicles on the road by comparison of images, switching the signal to red if the intersection is empty and to switch the signal to red despite a certain amount of cars present if a preset time is elapsed.

The similarity between the database image and the acquired image (image matching) provides the percentage of similarity used to calculate the duration that signal is switched on.

One limitation is if a lane is closed down, the calculated value would not be accurate as the image matching parameter is set with 100% operating efficiency of the intersection taken into consideration (Gonzalez and Woods, 2009).

In India and the US, a countdown timer along with the traffic signal is used commonly, research on this concept is extremely divided as there have been various benefits and negatives that have been concluded from various studies. A certain city where this technology has been in use for a long time has been surveyed, the drivers are used to them and are familiar with how they operate. Of all the received answers, 385 were useful; 98% of the respondents had driving licenses of passenger cars, 84% of the respondents considered the countdown devices a positive complement to the traffic signal, 10% considered them a negative complement and 6% of the respondents believed that countdown devices were simultaneously a positive and a negative complement.

Most of them (55%) believe that they are a positive complement because the driver is able to prepare in advance to start up and stop. Some (25%) believe that they are useful because they inform the driver about the duration of an individual phase. Only 8% are convinced that they reduce the number of accidents in intersections and 9% feel that they increase safety in an intersection. Because they had the opportunity to write their own opinion, 3% of the respondents chose other options.

Of those who consider countdown timers a negative complement, 32% believe they are negative because they disturb the driver and distract their attention. In addition, 32% believe that the presence of a countdown device increases the number of violations in intersections, 7% say that countdown signal disturbs them and 16% are of the opinion that it reduces safety in intersection. Other options in the survey were chosen by 13% of the respondents (Rijavec *et al*., 2013).

MATERIALS AND METHODS

An existing traffic control system works on one of the four principles listed as:

A micro controller: It is a device that controls most junctions with four sets of traffic lights. The control here is not flexible, it is not based on the traffic at the crossing and however there is a fixed time period for red, green and orange lights. These timing durations are varied as per the day according to varying levels of traffic.

A vehicle actuated control: It takes into account the green times of an intersection. The main drawback of this is that it does not take into account the number of vehicles waiting at red. This usually has a detector located at a distance. They will work well only if the flow of traffic matches the one assumed when unit extension of green is selected.

Manual controlling: This requires man power to control the traffic. Traffic police are allocated to certain intersections and they control the traffic. They should be stationed only in case of accidents/emergency and not as a regular means of controlling traffic. There are many factors that decide optimum flow of traffic and it is extremely difficult for an individual to make that assumption. The work load for these operators is very high since they need to constantly make decisions and are hence prone to error.

Automatic traffic light: It is controlled by timers and electrical sensors and the lights switch position according to the timer value however, there have also been traffic congestions in this case (Walad and Shetty, 2014).

In this study, we used edge detection and image matching as the two major factors in digital image processing to obtain an output via MATLAB since, all the simulation can be done on that software.

We treat the original image with noise to simulate a still image taken from a video, this is done with the help of the “imnoise” function on MATLAB. Figure 1a and b show the image before and after introducing noise. Adding noise to an image reduces the pixels and distorts the image slightly. The reason why we use this is to ensure that the system is able to detect and compare the two images.

Edge detection: To build a flexible traffic light controller based on density of traffic, edge detection techniques must be used. The criteria and techniques for edge detection is discussed:

Images containing varying shades of grey are called Gray scale image’s. These images are crucial for detection of edges and segmentation of images. There are three discontinuities that can be observed in a gray scale image: points, lines and edges. Using spatial marks we can detect

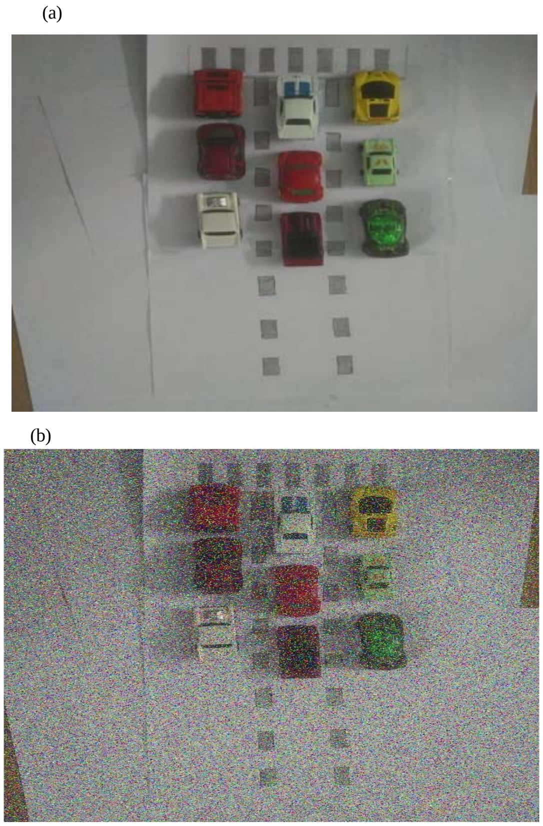

Fig. 1: a) Original image and b) Image after introducing noise

these discontinuities. The most crucial factor for a traffic signal is to detect edges. An edge is defined as a set of connected pixels that form a boundary between two disjoint regions. Discontinuity of scene features like brightness gives rise to edges. An edge is based on strength, edge direction and edge position. Different types of edges are step edge, ramp edge, roof edge, ridge edge (Brinda *et al.*, 2015). There are several criteria to define edge detection:

Good detection: The algorithm can detect edges in certain acceptable noise environments.

Good localisation: The edge location must be reported as close as possible to the correct possible position, i.e., edge localisation accuracy.

Orientation sensitivity: The operator not only detects edge magnitude but it also detects edge orientation correctly. Orientation can be used in post processing to connect edge segments, reject noise and suppress non-maximum edge magnitude.

Speed and efficiency: The algorithm should be fast enough to be usable in an image processing system. An algorithm that allows recursive implementation or separately processing can greatly improve efficiency.

In an ideal scenario, real time surveillance feeds can be obtained from the traffic junctions present. The development of this code can be separated into four sections:

- Image acquisition
- RGB to gray conversion
- Image enhancement
- Image matching

Apart from this, it is essential to produce a reference database which consists of preset images of the intersection at different intensities of traffic, these images will be compared with the real time images acquired by the aforementioned surveillance feed (Srinivas *et al.*, 2013).

Image acquisition: The first step of the process is to get the acquired real time image on MATLAB, since, this image is essentially a paused video of a moving vehicle, the quality of this image is extremely weak and would be inappropriate to compare this image without further enhancement (Hasan *et al.*, 2014).

Image resizing: Image scaling occurs in all digital photos at some stage in photo enlargement or a reduction in size. It happens anytime you resize your image from one pixel grid to another. Image resizing is necessary when you need to increase or decrease the total number of pixels. Even if the same image resize is performed, the result can vary significantly depending on the algorithm. Images are resized for various reasons, we use it here because a system is designed for one particular camera specification and will not run for another specification so it is necessary to make the resolution constant for the application to perform image resizing (Antonio, 2017).

Image enhancement: Figure 2 shows the original image from the database. The following two procedures that helps to make the image comparable:

RGB to gray conversion: Humans perceive colour through wavelength sensitive sensory cells called cones. Each cone has a different sensitivity to electromagnetic radiation of different wavelength. One cone is mainly sensitive to green light, one to red light and one to blue light. By emitting a combination of these colours, almost any colour can be detectable to the human eye. This is the reason behind why colour images are stored as separate

Fig. 2: Original image from the database

image matrices; one storing the amount of Red (R) in each pixel, one storing the amount of Green (G) and one storing the amount of Blue (B). In grayscale images, we do not differentiate how much we emit of different colours, we emit the same amount in every channel. We will be able to differentiate the total amount of emitted light for each pixel. Less light gives dark pixels and more light is considered to be bright pixels. When converting RGB to grayscale, we have to consider the RGB values for each pixel and make a single value reflecting the brightness out of that pixel as the output. Since, perceived brightness is often dominated by the green component, the method used to calculate average is as follows: 0.3R+0.59G+0.11B (Antonio, 2017; Charette and Nashashibi, 2009).

Image enhancement: This is the process of adjusting digital images so that the results are more suitable for display or further analysis. To take an example, we eliminate noise which makes it easier to identify key characteristics.

When images have a poor contrast, we have to reduce the spread of the characters before applying a threshold to the word image. So, we introduce "power-law transformation" which increases the contrast of the characters and helps in better segmentation. The basic form of power law transformation is:

$$s = c(r^\wedge\gamma)$$

Where:

r and s = The input and output intensities, respectively
c and γ = Are positive constants

A variety of devices used for image capture and display respond according to power law. The exponent is referred to as gamma so, the process used to correct

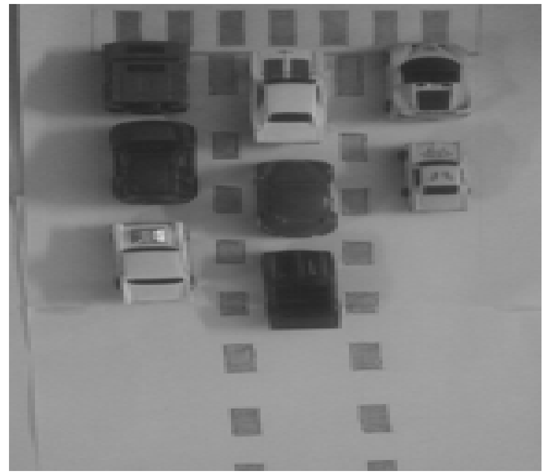

Fig. 3: Gray image

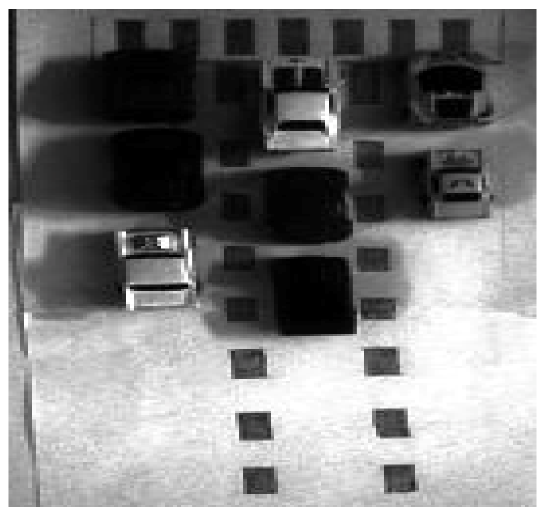

Fig. 4: Enhanced image using gaussian filter

these power law response phenomena is called gamma correction. Gamma correction is crucial in determining the display of an image accurately on a screen. To avoid rescaling the value of 'c' is fixed as 1 and the value of 'γ' varies from 1-5 (Antonio, 2017).

Image matching: Recognition techniques are based on matching each image with the prototype pattern vector as shown in Fig. 3 and 4. An unknown pattern is assigned to the image which is closest in terms of a predefined metric. The simplest way to classify this is using minimum distance classification which computes the distance between the unknown image and the prototype vectors of each image. It chooses the smallest distance to make a decision. There is another approach based on correlation, this can be formulated directly in terms of image matching (Gaikwad *et al*., 2014).

The image matching technique used here is comparing the reference image with the real time image pixel by pixel and although there are some disadvantages related to pixel based matching, it is one of the best techniques for the algorithm which is used in the project for decision making.

Real image is stored in a particular metric in the memory and the real time image is converted to the desired metric. For images to be same, the pixel values in the matrix must be the same. If there is a mismatch in pixel value, it adds on to the counter used to calculate number of pixel mismatches. The percentage of matching is expressed as:

$$\text{Match (\%)} = \frac{\text{No. of pixels matched successfully}}{\text{Total number of pixels}}$$

The image that is acquired by the system is a real time image of a surveillance system, mostly a still image of a video. This means that the image might appear distorted and would need to undergo enhancement techniques to make sure that the image can be compared with the image that is present in the database.

On MATLAB, we compare the two images by an algorithm called Principle Component Analysis (PCA). This algorithm is typically used for facial recognition or used to compare the similarity between two images. PCA algorithm stores the original real time images in a folder called the “train” database and the enhanced image is stored in a folder called the “test” database. The enhanced image is compared with all the images present in the database and the image most similar to it is shown as the output. There is an abrupt change in the gray level and there is an edge that is formed between two distinct regions, basically the edge is a border between two regions.

Here, edge detection locates the pixels in the image that correspond to the edges of the objects seen in the image and image matching pairs these two images together via the aforementioned PCA algorithm. Once these images are matches, the traffic light durations can be set (Beymer *et al*., 1997).

RESULTS AND DISCUSSION

The above paper presents the method of traffic light control through image processing. The earlier techniques had a drawback of time being wasted on green light on the empty road. Our implemented system avoids this problem. We have successfully implemented real time image processing based traffic light controller. This study illustrates that image processing is the best way to control traffic when it comes to real time feedback the principle component analysis system compares the two databases. The image from the database (left) is compared with the real time acquired image that has been enhanced (right). Once these images are compared, the image that is most similar to the enhanced image is shown in Fig. 5 and 6.

Fig. 5: Database image

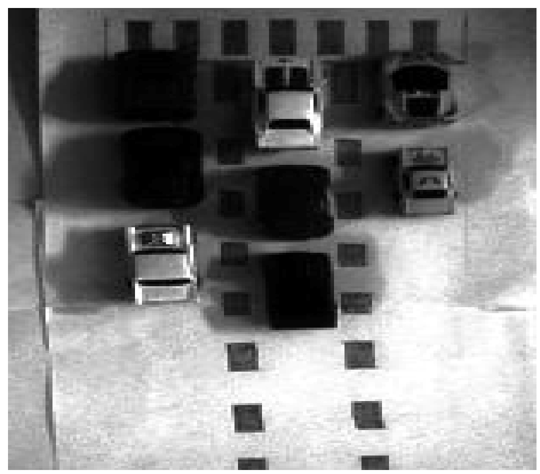

Fig. 6: Enhanced image

In addition to this, each image in the database will be linked to a duration that the signal needs to be switched on and when the image is matched with this particular image. It will be evident that the image needs to be switched on for that amount of time.

There should also be a timer present in the event that the junction is full and the time set for the signal to be switched on exceeds the maximum permissible time that the signal can be switched on. After image matching, certain preset times have been calculated for the intersection to be switched on:

- Result 1: when intersection is 0-30% full-green light on for 25 sec
- Result 2: when intersection is 31-50% full-green light on for 45 sec
- Result 3: when intersection is 51-70% full-green light on for 60 sec
- Result 4: when intersection is 71-100% full-Timer ensures the signal gets switched to red after the maximum permissible time of 70 sec (Chandrasekhar *et al*., 2013)

CONCLUSION

In this study, we discussed about existing traffic systems and the technologies used in them along with it's drawbacks. We use edge detection as the basic concept in image processing in identifying an image object, image segmentation and image enhancement. Each edge detection technique has its own advantage and disadvantage in various fields. We propose using digital image processing and PCA algorithm on MATLAB to compare two sets of databases; the acquired and the original database. The original database contains stock images of the junction at varying degrees of traffic. Each image is linked to a duration that the signal needs to remain switched on. The acquired database undergoes edge detection and image enhancement procedures to increase the pixels in the image and ensure the distorted image is capable of comparison with the original image. Once the two images are matched, the results linked to the original image can be calculated giving the operator a set time for the signal to be switched on. In the condition that the junction is at 100% traffic, there is a timer that ensures the signal does not stay switched on for longer than the preset time (Ferrier *et al*., 1994).

In the event of one of the lanes in the junction are closed, it might hinder this algorithm and finding a solution to this problem is part of the future scope of this paper. It would also greatly benefit the cause if real time CCTV footage of a junction is obtained as the database would instantly increase and experiments can be carried out on multiple scenarios. The focus in future could also be to implement a controller using DSP as it can avoid heavy investment in industrial control computer while obtaining improved computational power and optimised system structure. The hardware implementation would enable the project to be used in real-time practical conditions. We also propose a system to identify the vehicles as they pass by giving preference to emergency vehicles and assisting in surveillance on a large scale (Solomon and Breckon, 2013).

ACKNOWLEDGEMENT

The researchers would like to thank Prof. R.N. Saha, Director, BITS Pilani, Dubai for his constant encouragement and support.

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