Traffic flow measurement for smart traffic light system design

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Article Info

Article history:

Received Oct 19, 2022
Revised Jan 01, 2023
Accepted Feb 16, 2023

Keywords:

Image processing
Pattern recognition
Smart traffic light
Traffic flow management
Vehicle counting

ABSTRACT

Determining congestions on intersection roads can significantly improve the performance of a traffic light system. One of the everyday problems on our roads nowadays is the unbalanced traffic on different roads. The blind view of roads and the dependency on the conventional timer-based traffic light systems can cause unnecessary delays on some arterial roads on expense of offering a needless extra pass time on some other secondary minor roads. In this paper, a foreground extraction model has been built in MATLAB platform to measure the congestions on the different roads constructing an intersection. Results show a satisfactory performance in terms of accuracy in counting cars and in consequence reducing the wait time on some major roads. System was tested under different weather and lighting conditions, and results were adequately promising.

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1. INTRODUCTION

The massive increase in car production together with the substantial increase in the level of per capita income in Iraq, the country where I live, made streets flood with cars. This resulted a non-precedent road congestion making it intolerable to make car journeys. Cars jams in traffic lights definitely cause people inconvenience, especially for those they have urgent journeys. Ambulance and police vehicles as well often have to wait until these jams are resolved. This wastage in precious time could be very costy, especially when the matter is related to human lives. Furthermore, traffic jam is considered a major factor of car accidents. One of the reasonable solutions to road congestion problem is to manage vehicles' flow on streets. Crossroad flow management can significantly reduce traffic jams in cities. Although traffic light systems proved to be an effective solution, conventional traffic lights lack fairness in dealing with roads of different levels of congestions. It is really illogical to assign equal pass times to all the roads on an intersection since these roads are differently congested. Looking to streets in terms of traffic on them and assigning pass times according to these traffics would be a fair decision. Conventional traffic light systems assign similar pass times to roads on intersections, and therefore in many cases consume extra unnecessary time on minor uncongested roads. On the other hand, other crucial major roads which are highly congested may be offered a lesser pass-time than what is needed to resolve their congestions.

Image processing can be used as an efficient tool to measure road's congestions for its ability in efficiently analyzing videos and pictures. Although the task of counting the number of vehicles can be achieved using the traditional hardware detecting sensors, camera-based monitoring offers much more efficient facilities in terms of analysis capabilities. Image processing techniques can be used to recognize and differentiate among a wide range of moving objects, such as long vehicles, short vehicles, and pedestrians.

The traditional magnetometer and ultrasonic detectors need to be installed on roads causing damages to the surfaces of these streets [1], [2]. In contrast, cameras installation does not cause that damage. Looking at the matter from a cost perspective, it could be considered that cameras are already installed on road intersections for security purposes. Therefore, no additional cost is required.

Many algorithms have been proposed for traffic monitoring purposes. Several challenges appeared when researchers constructed their algorithms. Occlusion occurs when the inter-vehicle boundaries in crowded streets are difficult to recognize, which is considered one of these obstacles [3], [4]. In [5] also suggested an efficient way for detaching images of adjacent objects. In [6], [7] proposed different ideas to tackle this problem. Another issue is the narrow viewing range of monitoring which has been delt with by [8], [9] through using multiple cameras to extend the perspective. Tracking techniques have also been attached to vehicle counting as a beneficial capability of using vision-based traffic assessment. Shadow is still considered one of the big challenges facing researchers, in [10]-[12] made their contributions in this regard. Panoramic view has been suggested by [13] to provide a 360-degrees angle of surveillance.

Researches on this topic goes in two directions, some researches like [14], [15] adopted the idea of motion detection. In motion detection technique, the captured video is disassembled into frames, then successive frames are compared together in order to detect any moving object. This method is called frame differencing method [16]. In frame differencing method, the stationary background is separated from the moving foreground aiming to detect any moving object [16]. This can be achieved using Gaussian distribution approach, temporal/approximate median, Gaussian mixture model (GMM), or delta-sigma filters [17]. These techniques face some challenges such as when vehicles park temporarily or when lighting condition changes suddenly [17]. One of the major drawbacks of video-based surveillance technique is that the resulting accuracy is dependent on the amount of storage requirement [18]. On the other hand, some other papers such as [19] have been conducted on image-base analysis using several algorithms to recognize cars and vehicles. Pattern recognition algorithms, such as histogram of gradient (HOG) [20], scale invariant feature transform (SIFT) [21], convolutional neural network (CNN) [22] and Harr-like [23], were used in this perspective. These methods make use of some predefined visual features like color, shape and texture to recognize cars. Different shadowing and lighting condition still represent a big obstacle to this technique [24]. Many papers have been written to address these problems. In [25]-[28] focused on the shadowing problem, and proposed a method to eliminate shadows based on some prior knowledge of shadow visual properties. On the other hand, in [29]-[31] concentrated on the different weather and lighting conditions problem.

In this paper a new traffic surveillance algorithm supported with occlusion detection and shadow removal facilities has been proposed then applied to a traffic light timing to provide a smart traffic light system that is capable of giving different timing to the roads connected to an intersection depending on the level of congestion on these roads. This algorithm adopts the idea of extracting the foreground image by exclusive or (XOR)-ing the currently captured image with an empty street picture which has been stored in prior. The XOR operation is achieved in gray scale plane in order to reduce the amount of noise associated with different coloring and lumination conditions. The XOR operation can efficiently extract the various objects in the non-empty image. Applying different kinds of thresholds and filters can significantly enhance the algorithm’s accuracy by excluding some minor objects which are almost not vehicles.

2. METHOD

The proposed algorithm adopts the idea of XORing the currently taken street’s image with a pre-taken empty street image, termed here as background image, then determine the differences between these two images. The algorithm includes four phases. Firstly, the two red-green-blue (RGB) colored images, namely the background and live images, are gray-scaled in order to reduce the minor distinctions caused by coloring. More accurate results can be achieved if the gray-scaled images are further converted to binary black and white (BW) images in order to exclude minor brightness variations. The proposed algorithm takes into account the day/night scenes and sudden lighting changes by appropriately thresholding the gray-scaled images. A suitable threshold is determined by image histograms. After converting them to binary, the two constituting images are XORed to extract the foreground image. Tiny objects, which are more likely to be noise, are then excluded from the resulting foreground image. Pattern recognition technique is then applied to identify vehicle-like objects. Pattern recognition is applied to the currently taken image rather than the pre-defined empty street image aiming to count the number of vehicles on that street. The estimated number of vehicles per road is then utilized to assign a suitable traffic light timing that suits the congestion on that street. Figure 1 shows a schematic diagram of the proposed algorithm.

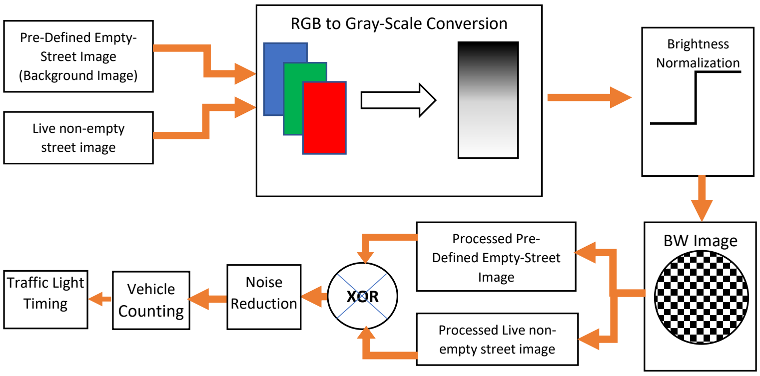

Figure 1. Proposed algorithm's schematic diagram

3. RESULTS AND DISCUSSION

Figure 2(a) and Figure 2(b) show the original background and live traffic snapshots respectively. The aim behind inputting these two images is to extract the difference foreground image which represents the pure traffic on the target street. These two images were firstly converted to gray-scale to provide better contrast levels. Thereafter, a histogram enhancement operation is utilized to obtain even a better resulting contrast in addition to processing the different weather and lighting conditions. These improved gray-scaled background and live traffic images are shown in Figure 3(a) and Figure 3(b) respectively. After that, the two images need to be further converted to black and white (BW). A suitable thresholding level was applied to obtain the BW background image in Figure 4(a), and the BW live traffic image in Figure 4(b). In order to extract the live image foreground, the background empty-street image is thrown away. This operation was achieved by XORing the both instantaneous live and background processed images. The resulting binary image is shown in Figure 5 which represents merely the traffic on the target street. Since it is impractical to have a completely similar background scenes of the road in two different time points, noise caused by tiny particles such as birds and insects have to be excluded from the traffic scene resulting in Figure 6 which gives the pure traffic scene. Adjacent white pixels construct white areas, which in turn are counted to determine the number of cars on the target road as shown in Figure 7. Testing the proposed algorithm on different streets with different lighting and shadowing conditions, it could be said that results shown a promising accuracy level in term of measuring the amount of traffic even in the presence of different shadow and lighting conditions.

(a) (b)

Figure 2. Original source images: (a) background image and (b) live traffic image

(a) (b)

Figure 3. Gray-scaled images: (a) background image and (b) live traffic image

(a) (b)

Figure 4. Binary black and white images: (a) background image and (b) live traffic image

Figure 5. Binary foreground image

Figure 6. Filtered foreground image

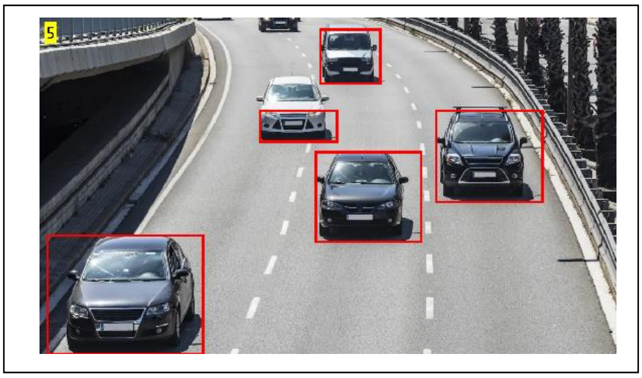

Figure 7. Counting number of cars

4. CONCLUSION

Background subtraction technique was used in this paper to determine traffic congestions through the different roads on a traffic light system. Two source images were fed to the proposed system in order to extract the foreground scenes from the instantaneous live street images which in turn reveal the amount of the traffic on these streets. These images are namely the empty background image which is a snapshot of the real street when it is completely empty, whereas the second image is taken periodically and compared to the empty background. The comparison is achieved here by XORing the two images. XORing two images will emphasize the differences. XORing was done in binary level instead of true color level. A big challenge was struggled here with the low level of contrast in white-colored vehicles, since the street looks dusty in the image. A contrast improvement strategy was used to tackle this problem through the use of histogram modification technique. In such a technique, the top and bottom 20% brightness levels were saturated and the remaining range was expanded to increase the level of contrast. It should be taken into account that the excessive histogram expansion definitely will result in a deficiency in the system's accuracy, therefore the range of expansion was selected carefully to obtain an optimal level of accuracy. Results show a very promising level of accuracy even in case of low contrast levels and for all cars' colors and sizes. Further researches can be conducted considering street foreground pixel density rather than number of cars. This idea could be adopted since car size may be taken in account when traffic congestion is determined. Other bikes motorcycles and even pedestrians could also result in an excessive traffic jam.

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