Traffic Monitoring Using Image Processing

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Rui Li
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Traffic Monitoring Using Image Processing

Abstract

Traffic monitoring involves the collection of data describing the characteristics of vehicles and their movements. Such data may be used for automatic tolls, congestion and incident detection, law enforcement, and road capacity planning etc. With the recent advances in Computer Vision technology, videos can be analysed automatically and relevant information can be extracted for particular applications. Automatic surveillance using video cameras with image processing technique is becoming a powerful and useful technology for traffic monitoring.

In this research project, a video image processing system that has the potential to be developed for real-time application is developed for traffic monitoring including vehicle tracking, counting, and classification. A heuristic approach is applied in developing this system. The system is divided into several parts, and several different functional components have been built and tested using some traffic video sequences. Evaluations are carried out to show that this system is robust and can be developed towards real-time applications.

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1. Introduction

Traffic monitoring systems that are used for traffic management and planning have a long history. In early stage, people designed devices such as inductive loop detectors [1] or microwave detectors [2] to collect traffic data. With recent advances in computer vision and video technology, traffic monitoring using image processing becomes popular.

Nowadays, people have to deal with worsening traffic conditions in urban areas or even in suburb areas due to the fast development of cities. Long time ago, people tried to add more lanes or built motorways around the city centre to avoid congestion. Nevertheless, it becomes less and less possible to build more roads. Using the existing road and rail network more efficiently is the only solution. In order to achieve this goal, acquiring better and more accurate traffic data becomes more and more important.

Advances in electronics make powerful hardware available for acquisition and processing of images and videos at low costs. Automatic surveillance using video cameras with image processing technique is a powerful and useful technique for traffic monitoring. Traffic monitoring systems can be used in pavement analysis and design by measuring traffic volume and environmental conditions and evaluating system performance. It can be used in road design modification by classifying vehicles, recording traffic flows, detecting and predicting accidents. It can be used to support freeway or motorway management by analysing traffic volumes and tracking vehicles. Other applications include defining control decisions, providing travelling information for publics, supporting operations functions, planning special event and emergency management.

In this thesis, we propose a system that analyses image sequences captured by a camera, which can be mounted on a bridge over a road or installed near a traffic light to detect running vehicles, and obtain further traffic information for monitoring use. This system is robust and a real-time application can be developed based on the system developed.

1.1 Motivation

The work presented in this thesis has the potential to be immediately applied in the area of traffic monitoring using image processing. The developed algorithm can be incorporated with powerful hardware such as embedded system: Field Programmable Gate Array (FPGA), Digital Signal Processor (DSP) to make real-time monitoring come true. The required hardware involves a static camera mounted on a bridge or installed near a traffic light, a set of data transmission cables to transmit collected data, a FPGA or DSP board that is connected to a PC to process data, and the PC can be used to control and perform monitoring functions. If received data can be processed quickly enough to satisfy real-time requirements, the key frames showing any accident or danger need to be written out and stored. In this way the storage space for the whole video sequence can be reduced.

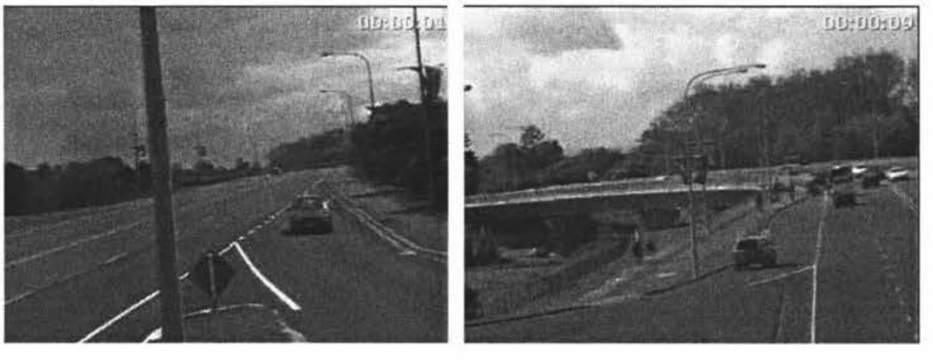
The main tasks of this system are to detect moving objects including pedestrians, bicyclers, motorcyclers, and vehicles, vehicle tracking, vehicle counting, and vehicle classification. The tracking function can track vehicles, and record the trajectories travelled by vehicles, which can be further used to calculate the speeds, accelerations of the vehicles. These can be used in speeding control. Through tracking, road hazards like unusual reversing or turning can be detected, and warning can be given out by writing out an image showing that scene. When these happen, abnormal trajectories will generate, the system can justify through analysis of the trajectories. For example, if one vehicle is trying to turn right at a corner that is forbidden to, the curvature of its trajectory will be greater than the predefined threshold, it is described as a dangerous vehicle.

The work can be extended to automatic security and surveillance use on/in buildings or on roads. The camera can be installed on the wall outside a building or at the entrance of a building to monitor the entrance of the building. The human bodies are detected and recognized by a computer, and these blobs can be tracked and recorded. Through further development, functions such as recognising different people and their actions can be added in. Action recognition is a key role in active surveillance. The algorithm can be further developed towards human computer interaction. A camera is used to monitor and capture actions from the user, the computer system can analyse actions and give response.

1.2 Problem description

One stationary camera, mounted on a bridge over a road is used to monitor the whole road. The resolution of these images is 320 x 240 pixels due to the limitation of real-time. The original video sequences are in uncompressed RGB format, then a piece of software called hero (http://www.kingsoft.com) is used to sample the images from the video sequence at a rate of 20 frames per second. There are 8 bits to represent each colour component, which gives 256 steps of intensities. Then these images will be stored in a hard disk for further processing. Figure 1.1 shows one example traffic image. In our thesis, in order to develop and test our algorithm, we capture traffic videos from several different scenes, and some of them focus on pedestrians and bicyclers. Figure 1.2 shows other traffic images.

Figure 1.1 An example traffic image



(A) (B)

Figure 1.2 Two other traffic scenes (A) a vehicle is turning left at the corner (B) a vehicle at a corner that is merging to the main road.

There are many conditions to be considered in developing a traffic monitoring system. In image sequence capturing stage, the weather, lighting conditions of the outdoor scene, the position of the camera can be diverse. These would result in images of different quality. Environmental conditions are also considered, for example, some parts of the vehicles will be blocked by tress or buildings near the road, or even totally merged by them. The captured images contain a lot of information, such as vehicles, trees, pedestrians, traffic lights and so on. After detection, it is necessary to identify which objects are expected to be kept and which should be ignored. Waiting or stopping vehicles are also required to be kept monitoring instead of treating them as static objects.

In order to make real-time application possible, the algorithm is developed based on some assumptions to make the algorithm simple but robust. For example, in the background updating process, we assume that the monitoring area is small enough that the intensity change is the same for the whole area. Hence we only select four test areas for intensity change checking. In some situations, captured traffic frames could not satisfy the assumptions we made. For example, if cloud comes to cover only the area of testing areas, the updating still performs and makes the rest area darker than the actual situation. Although we make some changes in our algorithm to make the algorithm robust enough, some situations are still not solvable. For example the length and the shapes of shadows are changed by the movement of cloud. These changes affect the results of shadow handler. However, the developed algorithm is still good enough for real-time application.

After monitoring, the processed images will be added together to form an avi format video and play back. The flow chart of traffic monitoring using image processing in our research can be viewed as follow:

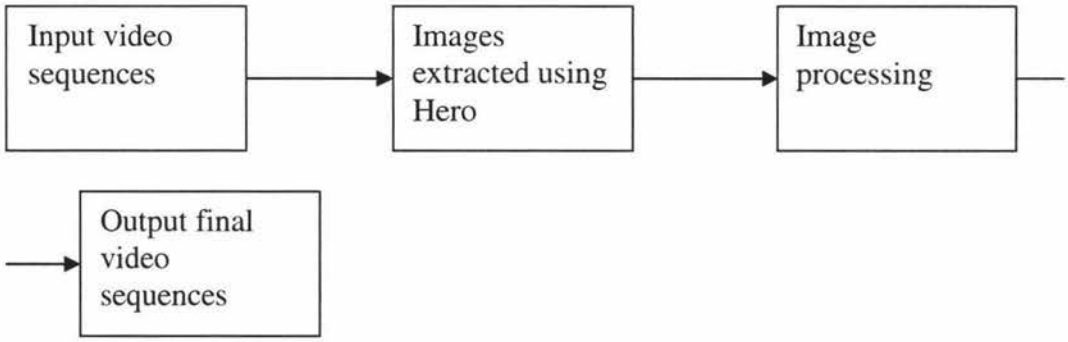


Figure 1.3 Brief flow chart of the algorithm

1.3 Block diagram of the algorithm

In this section we present the processes we used during the development of this thesis. Figure 1.1 shows the flow chart diagram of the processes.

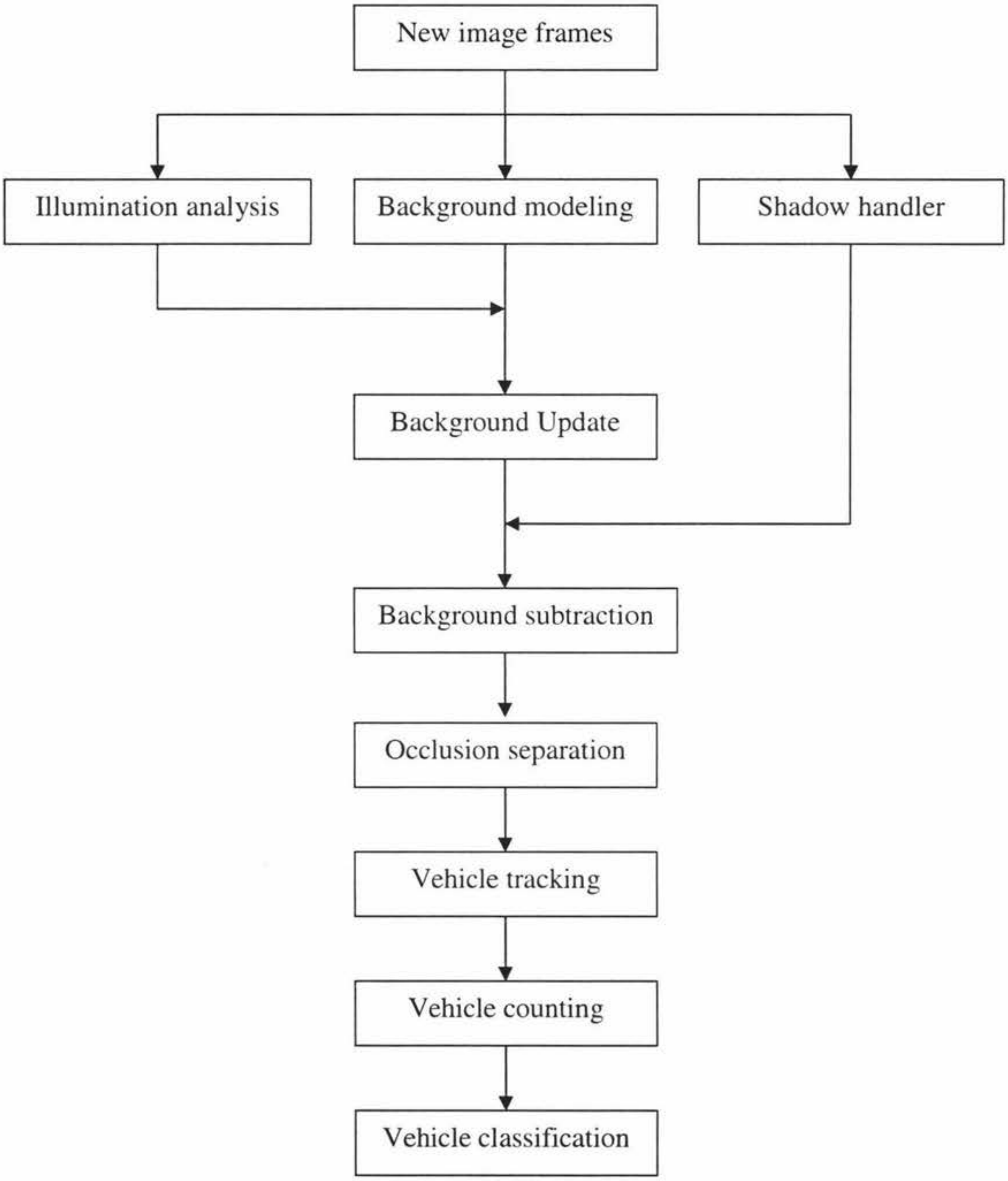


Figure 1.4 Processes of traffic monitoring

New video sequences that are captured by a camera are input to a PC. Then a piece of software called hero (or other software that can sample video sequences) is used to get the image samples of the video sequences at a frame rate of 20 frames per second. These images sequences will be stored in a hard disc and then be input to the system.

The first step of the algorithm is to model and update the background image for background subtraction. The first 200 input image sequences (first 10 seconds of traffic scene) are used to model the initial background image using the averaging techniques. At the same time, each image is processed with illumination analysis. Illumination analysis is used to get the direction of the light source such as sunshine. This information is used define the direction of the shadow. Shadow handler is used to remove shadows in image sequences. Then these processed images are used to update the modelled background.

In the background updating stage, we use next 200 images to classify each pixel in each frame into either static background pixel array or dynamic background pixel array by comparing incoming images with the modelled averaged background image. Once all pixels are separated, averaging background updating is used on static background when necessary. At the same time, current dynamic background pixels are used to replace the original pixels at the corresponding places in the averaged background image if they are not covered by foreground objects.

Once an accurate background is built, this background image is subtracted from the current traffic image to obtain foreground objects. Through some other techniques such as edge detection, opening, or closing, only foreground objects including pedestrians, bicyclers, motorcyclers, and vehicle stay in the image. Rough contours of those objects can be extracted. Followed by the snake method [85 - 89], refined contours representing objects are constructed for tracking.

Our tracking algorithm is the combination of region-based tracking and contour-based tracking. Through energy minimization method (snake), we get accurate contours that bound detected objects. Then these contours are used to obtain the corresponding regions for detected objects. Region-based tracking is used to track all objects.

Before tracking, occlusion separation is used to separate two or more vehicles that are partially or totally occluded with each other. Tracking is separated into fast moving objects (vehicles and motorcycles) tracking and slow moving objects (pedestrians and bicyclers) by travelling speed. The tracking algorithm for these objects is the same, apart from the tracking frequency. Tracking is performed by recording the coordinates of the bounding boxes and the centroids of blobs that representing found objects. Histogram is used to separate two or more close vehicles. Objects are first classified into fast moving objects and slow moving objects by speed. For slow moving objects, single pedestrian and bicycler are defined as one category. Multiple humans and slow moving or stopping cars are classified by using the compactness of them.

1.4 Contributions

The following points are the major contributions from this research.

1. A complete traffic monitoring system that combines a set of effective and efficient methods, which has the potential to be developed to fulfil real-time processing, has been developed. Experimental results show that this algorithm is robust and effective.

2. An improved method that divides the background into static background and dynamic background for updating separately has been implemented. This method can provide accurate updating of background image with less computational load.

3. A modified approach that combines the benefits of region-based tracking and contour-based tracking to increase the efficiency and accuracy of vehicle tracking has been developed.

1.5 Functional overview of the system

The system has the following functions:

a. Detection of vehicles

Detecting all moving objects in the scene, including pedestrians, cyclists, and vehicles. Recognizing and separating vehicles from them according to the properties of vehicles such as speed, volume.

b. Track vehicles in the scene and extract traffic data

When a vehicle enters the monitoring area, its position (coordinates in the window) is recorded. The coordinates used in the tracking system are a relative set of coordinates. Tracking is conducted by recoding the change of coordinates according to some stationary objects within a static scene. Some other features such as histogram are used to distinguish closed vehicles. The coordinates of bounding box and centroid are recorded. Some functions like shadow detection and elimination, occlusion separation are used to reduce tracking errors. Stopped vehicles are required to be recorded, and be tracked again when they start to move.

Associated with tracking, traffic data such as velocity, acceleration, trajectories are recorded. Through the analysis of trajectory, any incorrect entries at corners or intersections are recorded and output. Through the speed measure, any speeding behaviours will be detected.

c. Count vehicles in the monitoring area

When a new vehicle enters the testing area, its coordinates will be recorded and the system treats it as a new vehicle and counts it. When it leaves the testing area, the system will automatically terminate tracking

d. Classify vehicles

All the detected and tracked vehicles will be classified into two different categories according to their properties like the length, width and compactness.

1.6 Scope of this thesis

This thesis is organised as follows:

Chapter 2 presents a literature review in the areas related to our work including background modelling and updating, vehicle detection, shadow detection and elimination, occlusion separation, vehicle tracking, vehicle counting, vehicle classification, and segmentation. Also some materials related to our work such as colour space are discussed.

Chapter 3 describes the algorithm we used to initialize, model and update the background. After the background subtraction, foreground objects are extracted and presented by contours. A snake operation is used to refine contours so that not much background information is included in the contours.

Chapter 4 describes illumination analysis followed by shadow handler in our algorithm.

Chapter 5 describes the tracking methods we developed in our algorithm. First, occlusion separation method is introduced. Through tracking, trajectories of vehicles are recorded and vehicles' information is obtained. These data will be further used to monitor traffic flow. Through tracking, vehicle counting can reach an accurate result. Vehicle classification is also discussed.

Chapter 6 shows the results from the testing of the system using several different traffic videos. We use both quantitative and qualitative evaluations on the results. A discussion is also included.

Chapter 7 draws the conclusion of this thesis. In this chapter, main findings and conclusions are presented, followed by a discussion of the future directions about our work.