AAU PhD Degree
Tentative Detailed Plan of Research

Title:

Machine Vision Based Traffic Surveillance Using Rotating Camera

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Signature

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Date	Head of Doctoral Programme	Prof. Gert Frølund Pedersen

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Machine Vision Based Traffic Surveillance Using Rotating Camera

1 Research work Summary/Abstract :

Generally in surveillance system, sensors like microphones, cameras, motion sensors, proximity sensors, and location sensors like GPS are employed. Among all these sensor systems, video sensors are one of the most popular and promising ones due to decreasing cost of hardware and many other significant benefits. Automatic analysis of video sequences from traffic surveillance cameras is a challenging field. The research work in this field has a great impact on intelligent transport systems (ITSs). Due to sensor's easy maintenance and the low cost of monitoring and analysis, video sensors are increasingly used in ITS for traffic evaluation and management, driver assistance and some safety related applications.

It is found that stationary cameras are used more widely in many infrastructures than rotating cameras, which can rotate from zero to three hundred sixty degrees. Though, there is wide use of stationary cameras, in city like Pune (India), from where we are getting datasets, has around twenty percents rotating camera in its traffic surveillance network. Another motivating factor for use of rotating camera is, in case of large camera network, there will be drastic reduction in number of used cameras. This results in cost reduction and energy saving.

Most crucial aspect of any visual surveillance system is to develop accurate and efficient algorithm for object detection, tracking and analysis of the generated results. With the employment of rotating camera, complexity of the various algorithms for background estimation and object tracking increases. Further, urban traffic surveillance is more challenging due to high traffic density and various users of the road. We aim, to address these issues in this research work.

Inefficient transportation management and traffic control fail to keep pace with increases in population and car uses. This results in roadway congestion and road accidents. The impact of congestion can be minimized by accurate measurement of real time traffic conditions. We also aim to find the mechanism that evaluates traffic conditions based on traffic flow and the traffic density. Here, traffic flow can be defined as rate of vehicle passing at a given point on the road. Normally it is given in terms of vehicles per hour. Also, traffic density can be defined as the number of vehicles present on a given length of the road. It is given in terms of the number of vehicles per kilometer.

It is worth to mention here that, standard datasets and benchmark challenges are not available. This further increases difficulty level of direct comparison of our proposed algorithms.

2 The scientific content of the PhD project:

a. Background for the project

Visual surveillance is an active research area in computer vision. In this, interesting moving objects are detected and tracked from frame to frame [1]. Also, analysis of tracked objects is done for traffic parameter estimation.

A typical vision based traffic surveillance system, shown in figure 1 usually consists of two components, a sensor based traffic data collection system and a raw data process and evaluation system. In the scenario of traffic surveillance, objects are the vehicles. Vision-based vehicle detection is very challenging due to significant variation within class variables. For example, vehicles may vary in shape, size, and colour. Detection is also affected by complex outdoor environments (e.g. shadows), unpredictable interactions between traffic participants and cluttered background. Significantly, in traffic surveillance, vehicle detection algorithms need to process the frames real-time or at least close to real-time.

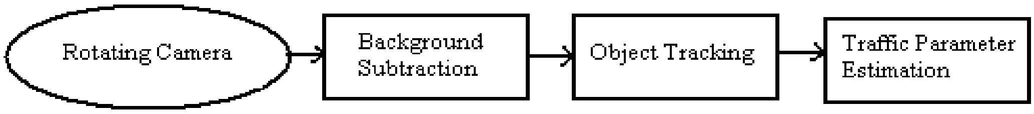


Fig. 1 General framework of a vision based traffic surveillance system.

A common approach for detecting moving object/vehicle from a video sequences is background subtraction. Objects are identified from the incoming video frame that differs significantly from the background model. While developing the model, many challenges are need to be addressed. Some of the challenges are robustness for illumination changes, non-detection of stationary background objects and shadow of moving objects. When surveillance is for urban area, traffic density becomes a more challenging one. This may cause vehicle occlusions, which is another important issue in the surveillance system. Also, shadows are the major factor to cause vehicle occlusion. The occlusion is one of the reasons for failure of vehicle detection. This results in degradation of the accuracy of vehicle tracking, classification, and counting.

In visual surveillance system vehicle tracking is an important step. Generally, vehicle paths are measured by means of tracking from a given video sequence. Also, it is possible and necessary to bypass the relatively time consuming operation of vehicle detection on a certain image frames because a traffic surveillance and management system requires to process the traffic video in real-time.

b. State-of-the-art for the PhD project

In video surveillance, detection of moving object from a video sequence is an important and critical task. It is found that in visual surveillance applications, stationary cameras are used widely than rotating one. Hence, state-of-the-art presented over here is influenced by this fact. We believe this can motivate us in developing various algorithms for a rotating camera.

We refer general frame work of a visual traffic surveillance system for presenting the literature survey.

Background Subtraction

A well accepted approach for identifying the moving objects is background subtraction [2]. Many background subtraction algorithms can be traced out in the literature. Most of them follow a simple flow diagram shown in Figure 2. In this approach, every incoming video frame is compared against a background model. Pixels in the current frame that deviates significantly from the background are considered to be moving objects. These ‘foreground’ pixels are further processed for object localization and tracking. As background subtraction is often the first step in many computer vision applications, the extracted foreground pixels should correspond to the moving object accurately. Even though, many background subtraction algorithms have been proposed in the literature [3] [4] [5], the problem of identifying moving objects in the complex environment is still far from being completely solved.

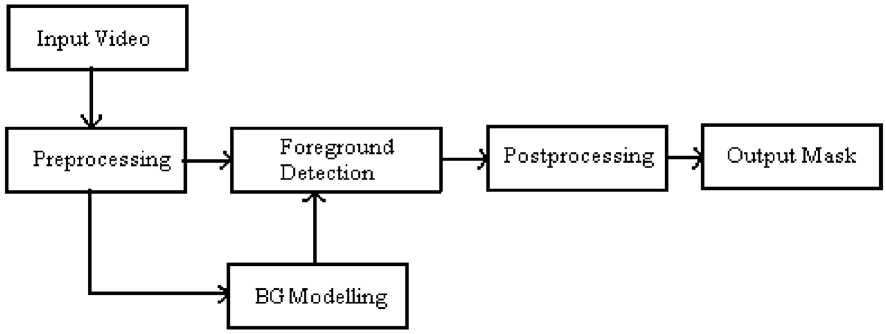


Fig. 2 Flow Diagram of a Generic Background subtraction Technique.

For a stationary camera, the background is relatively static. Here, moving objects can be segmented from the background just by frame differencing followed by some threshold. If the video streams are acquired by a camera mounted on a moving platform, then they have to utilize a stabilization algorithm in order to compensate the camera motion.

The complex traffic at the intersection also poses challenges to a background subtraction algorithm. The vehicles move at a normal speed when the light is green and stops when it turns red. The vehicles then remain stationary until the light turns green again. A good background subtraction algorithm must handle the moving objects that merge into the background and then become foreground at a later time. In addition to accommodate the real-time needs of many applications, a background subtraction algorithm must be computationally inexpensive and should have less memory requirements. With these constraints also, it is required to accurately identify moving objects in the video [6].

Preprocessing

In most computer vision applications, simple temporal and spatial smoothing is used in the early stage of processing which helps in reduction of camera noise. For real-time systems, frame-size and frame-rate reduction are commonly used to reduce the data processing rate. If the camera is moving, frame registration between successive frames is needed before background modeling [7]. Frame registration does the alignment of frames into the same coordinate plane. For a small camera motion, registration can be performed using spatial transformations such as affine or projective transformations [8].

Background Modelling

Main characteristic of a Background Subtraction algorithm is how it is defined and how its background model is updated. Background modelling remains at the heart of any background subtraction algorithm. Much research has been devoted to develop a background model which is robust against background environmental changes. It should also be sensitive to identify all moving objects of interest. There are two broad categories of background modelling technique, recursive and non-recursive.

- **Non-recursive Techniques**

Normally, a non-recursive technique uses a sliding-window approach for background estimation. It stores a buffer ‘L’ of the previous ‘n’ video frames and estimates the background image from the variation of every pixel within the buffer. In this technique requirement of memory is high as compared to recursive technique.

Some of the commonly-used non-recursive techniques are:

a. Frame differencing (FD)

This is simplest method for foreground segmentation. Moving objects can be segmented from the background by differencing the two consecutive frames (on pixel by pixel level), followed by some type of thresholding. Simple thresholding can result in partial extraction of moving objects. Though this technique is very fast, it has some limitations as follows:

1. It can not detect stationary vehicles,
2. Speed variation of vehicles can cause errors in detection,
3. It can not give accurate results in abrupt illumination changes environment and in the movements in the background.

b. Median filtering

Median filtering is most commonly used background modelling techniques [9, 10]. In this technique, value of every pixel in the background model is a median at each pixel location of all the video frames in the buffer. Decision for size of buffer is the important issue in this approach. Extension of Median filter is done by replacing median with mediod for colour video frame [9].

c. Linear predictive filter

In this approach, background is estimated by applying a linear predictive filter on the pixels which are stored in the buffer [11]. A drawback of this technique is that it is not suitable for real-time applications like visual surveillance.

- **Recursive Techniques**

Recursive techniques of Background Modelling maintain a single model of background, which is updated with each new incoming video frame. These techniques consumes less memory and are computationally more efficient than non-recursive one.

Some of the representative recursive techniques are:

a. Kalman filter

This is a widely used recursive technique for tracking linear dynamical system. This is simplest background model which assumes that pixels intensity can be modelled by a Gaussian distribution. Further, mean and variance of the background can be updated using simple adaptive filters to accommodate lighting changes or incoming of the object in the scene. In [12], each pixel is modelled with a Kalman filter thereby introducing robustness to lighting changes.

b. Mixture of Gaussians(GMM)

In Video surveillance applications, the scene is dynamic in nature. The pixel intensity value of the dynamic background varies significantly with time. Also, pixels intensity distribution is multi-modal. Therefore, we can not use the single Gaussian model for representation of dynamic scene background. In such situations, the pixel intensity is modelled by a mixture of Gaussian distributions to model significant variations in the background. In general, the pixel intensity is modelled by a mixture of K Gaussian distributions. K is fixed from 3 to 5 in the most existing literatures. Exploration of the GMM can be found in the literature [2, 7, 13, 14, 15]. It is found that GMM model proposed by Stauffer and Grimson is used widely due to good compromise between robustness, less computation time and memory requirement. Also, this model reduces the effect of small repetitive motions of branches of a tree, ripples of water on a lake and small displacement of camera.

c. Approximated median filter

In this approach, modelling of a pixel is done without Gaussian distributions. In [16], uses a recursive filter for estimation of the median. The running estimate of the median is either incremented by one if the input pixel value is larger than the estimate or decremented by one if it is small. This technique is simple, computationally efficient and robust to noise.

Vehicle Tracking

In traffic surveillance and management system, the processing of the traffic video in real-time is required. The trajectory of a moving vehicle is an important aspect for improvement in incident detection by detecting stopped vehicles within the camera's field of view. The vehicle tracking system can also produce count of vehicles, which could lead to better traffic flow estimation. Thus, after segmenting the traffic image frame and localizing the vehicle, the segmented vehicle with their bounding boxes are expected to be tracked in the next several frames.

Generally, tracking is performed by generation of features of the object and establishing correspondence between the regions of consecutive frames [17].Tracking techniques can be grouped into Point Tracking, Kernel Tracking and Silhouette Tracking [18].

Post processing

Generally, the output of a foreground segmentation algorithm is noisy. It also comprises isolated foreground pixels, jagged boundaries and moving shading [6]. Post processing is an essential step for improvement in segmented output. The simplest post processing techniques are median filters or morphological operations. In median filter approach, small group of pixel are removed that differs from their neighbours. Whereas in morphological approach object boundaries are smoothed. Suppression of moving shadow is more problematic then smoothing operations. The shadow detection algorithm aims to prevent moving cast shadows so as to improve background update and under segmentation problem.

c. Project’s objectives

A traffic surveillance system has several challenges. First and foremost is in object detection. Here, we come across background with varying lighting conditions and variation in class variables (e.g. colour and shape of car). Detection is also affected by complex outdoor environments and cluttered background. Also, due to high density of the vehicles (as our datasets are from Indian scenario, where this holds true) tracking becomes challenging. It is also found that, very little work is done, which specifically deals with the challenges associated with the rotating camera as a video sensor.

In this research work we consider rotating camera as our sensor and attempt will be made to address the challenges mentioned above. To name a few, development of accurate and efficient algorithm for detection of car as an object. Employ some pre-processing and post-processing algorithms in detection phase. Attempt will be made for development of aaccurate vehicle tracking algorithm for above said scenario. Further, estimation of the traffic parameters such as a traffic flow and density will be done.

d. Key methods.

The research will be based on theory-assisted design and application to practical situations. We use the open source OpenCV-library, which is implemented in C and C++. The library offers a broad range of computer vision functions and allows an easy link to our rotating camera prototypes. We also use MATLAB for implementing our various algorithms. We have our own datasets[1] of traffic at an intersection. The video sequence used is of 352x272 images.

In the first stage of the research, an efficient and accurate background subtraction technique for object detection will be developed and tested. The effect of pre-processing and post-processing in object detection will be evaluated. Further, novel algorithms for object tracking will be developed and implemented. Lastly, traffic parameters will be estimated.

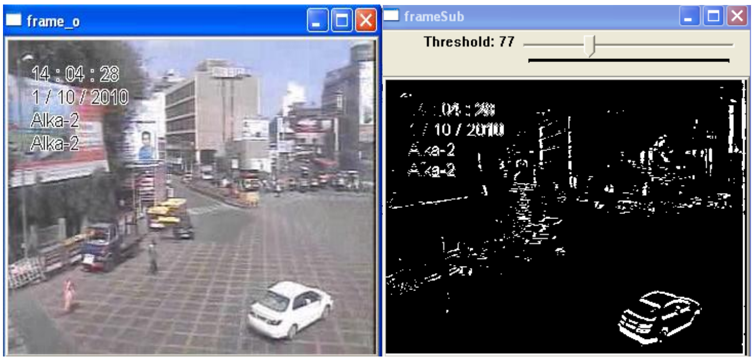
[1]Courtesy Pune Municipal Corporation

e. Experiences and results obtained so far and Projects expected outcome

Results obtained so far:

As our sensor is a rotating camera, motion of camera has to be compensated before developing object segmentation algorithm. With the help of computation of perspective transform, camera motion compensation can be achieved. Then, frame differencing (FD) can be used for achieving moving object detection. With this motive, we computed perspective transform between every two consecutive frames. In this approach, current frame (t=0) is transformed with computed perspective transform. Then, next incoming frame (t+1) is subtracted from this transformed frame for moving object detection. We repeated this process till last frame, thereby applying adaptive perspective transform for camera motion compensation and then achieved moving object detection. Results are shown in Figure 3(a).

To get improvement in output results, we tried background subtraction technique for object detection. We use adaptive Gaussian mixtures to estimate the background model. Initially, we build background model for approximately every frame that comprises one complete rotation of the camera. Onwards, based on this statistical model, a pixel in the current frame is classified as belonging to the foreground or background. We got better results than previous ones, which are shown in Figure 3(b).



(a) Adaptive Perspective transform

(b) Gaussian mixture model

Fig. 3 Result of (a) Frame differencing, (b) Background subtraction technique.

Expected outcome:

The expected outcome of the research is to develop accurate algorithms for detection of vehicle as object from the rotating camera. Further, algorithm for tracking of these objects will be developed. Finally, estimation of traffic parameters, such as traffic flow and the traffic density will be made.

f. Time schedule with milestones

Task		Year 1				Year 2				Year 3			
1	Background Study	■											
2	Literature survey	■	■	■									
3	Requirement gathering and analysis. Feasibility study.		■	■	■								
4	Novel concept development and Problem Specification and Delineation			■	■	■							
5	Background subtraction for object detection and processing					■	■	■					
6	Pre and post-processing for object detection							■	■				
7	Development and testing of vehicle tracking algorithm								■	■	■		
8	Estimation of the traffic parameters										■		
9	Journal and Conferences papers							■		■		■	
10	Writing of the Thesis											■	■
11	Stay Abroad		■	■	■		■	■	■	■	■	■	

* I will attend courses organized by Aalborg University through video conferencing and courses related to my research area in well known Institutes in India.

g. Outline of the Content of Thesis

Thesis will be a monograph and below is the brief outline of the thesis.

Acknowledgement
Abstract
Table of Content
List of Figures
List of Tables
List of Abbreviations
Chapter 1: Introduction
1.1 Motivation and Thesis aim
1.2 Thesis Contributions
 1.2.1 Problem Statement
 1.2.2 Summary of Contributions
1.3 Thesis Outline
Chapter 2: Object Detection and Processing
2.1 Introduction
2.2 Pre-processing
2.3 Background Subtraction
2.4 Post- Processing
Chapter 3: Moving Object Tracking
3.1 Introduction
3.2 Kernel Tracking

3.3 Silhouette Tracking
3.4 Traffic Parameter Estimation

Chapter 4:Implementations

4.1 Implementation Environments
- 4.1.1 Parameters
- 4.1.2 Assumptions

4.2 Scenarios
4.3 Results Performance Evaluation, Analysis and Discussion

Chapter 5:Conclusions and Future Work

5.1 Conclusions
5.2 Future work
Appendix (Reference)

h. Publications

Submission Plan

[1] Shivprasad Patil, Zheng-Hua Tan, Ramjee Prasad, Sudhir Dixit "Moving Object Detection using Statistical Background Subtraction for a Rotating Camera" (Working Title), In a conference on Selected Areas in computer vision. (Third Quarter 2011)

[2] Shivprasad Patil, Zheng-Hua Tan, Ramjee Prasad, Sudhir Dixit "Detection and Tracking of Moving Objects in Urban Traffic Video Surveillance" (Working Title), In a journal on Selected Areas in computer vision (First Quarter 2012)

[3] Shivprasad Patil, Zheng-Hua Tan, Ramjee Prasad, Sudhir Dixit "Traffic Parameter Estimation in Urban Traffic Video Surveillance" (Working Title), In a conference or journal on Intelligent Transportation Systems (Third Quarter 2012**)**

3 Agreement on the relationship between supervisor and student

The student-supervisors agreement can be summarized as follows:

- The student and the supervisors are together responsible for time management in the project. Time plan for the Ph.D. study should be reviewed every six months.
- Supervisor, Co-supervisor (India) will provide technical assistances.
- At least two meetings per month while at SIT and weekly meeting while at AAU.
- Most meetings are scheduled and arranged jointly by the student and the supervisors. In case of special needs, both student and supervisors can call for a meeting.
- E-mail and Skype contact is always welcome from both parts and often rapidly answered.
- Minutes will be made for video/telephone conferences.
- Feedback regarding the progress and quality of work will be given during the meetings and conferences.
- Agenda will be provided by the student one day prior to each meeting.
- Every year, for three months PhD Student will be in direct contact with Supervisors at AAU and telephonic and video conferencing meetings with Indian co-supervisor. Remaining nine months PhD Student will be in direct contact with Indian Co-supervisor and Telephonic and video conferencing with AAU Supervisors.
- The student is a staff member of both AAU and SIT and gets involved in group activities in both places.
- Paper writing is on the basis of collaboration between the student and the supervisors. In most of the cases, the student prepares the first draft and the supervisors give feedback and comments timely.
- Supervisor will read, correct and advise on the writing process of the thesis.
- This agreement will be evaluated every six months.

4 Plan for PhD courses *

Courses	Place/ Organizer	ECTS	Joint or Project course	Status
Introduction To Internet Of Things	Nilee Prasad, Albena Mihovska, Zheng-Hua Tan, Ole Brun Madsen, Aalborg	1	Project	Completed
Intellectual Property Rights	Lisbeth Tved Linde	2	Joint	Completed
Vehicle Communication	Tatiana Kozlova Madsen and Hans-Peter Schwefel	3	Project	Completed
Machine Learning	Assoc.Prof. Zheng-Hua Tan	3	Project	Completed
Air Interface Design for Future Wireless Systems – Towards Real 4G and Cognitive Radio	Prof. Ramjee prasad Prof. Frederikson Suvra Shekhar Das Nicola Marchetti	4	Joint	Completed
"Sensors and RFID Network"	Nilee Prasad Prof. Pedro Jose Marron	3	Joint	Completed
Bayesian Statistics, Simulation and Software – with a view to Application Examples	Associate Professor Kasper K. Berthelsen	4	Joint	Completed
An Introduction to Qualitative Research Approaches in Technology, Science and Education	Professor Paola Valero and Professor Tim Richardson	3	Joint	Applied
Writing and Reviewing Scientific Papers, Fall 2	Professor Jakob Stoustrup	3.75	Joint	Applied
Professional Communication	Professor Anette Kolmos	2.5	Joint	planned
Computer Vision	Assoc.Prof.Volker Krüger Copenhagen Inst. of Technology, Ballerup	3	Project	Applied
Subtotal (Planned)		**32.25**		
Total (Completed)		**17**		

*Based on the PhD Courses Catalogue, list may change according to the courses available in India.

5 Plan for dissemination of knowledge and findings from the project

- Most of the findings from the research work are going to be published in official conferences and included in the IEEE database according the standard proceedings.
- Furthermore, depending on the quality of the future results, other ways of dissemination as newspaper articles, seminars, etc. will be considered.
- Depending on the solution and the application, some findings can be published in journals.

6 Agreements on immaterial rights to patents, etc. produced during the PhD project.

The outcome of the research work will be registered for IPR and all the rights will be shared between the Aalborg University and the PhD student, following the standard procedures at AAU.

7 Plans for external collaboration

I will try to actively engage in Hewlett-Packard Labs, Banglore (India) research environment.

8 Financing budget for the PhD project

- CTIF, Aalborg University will provide the research facility.
- Expenses for tuition fee, lodging, boarding and travel will be borne by STES, Pune (India).

9 Short References

[1] A. C. Sankaranarayanan, A. Veeraraghavan, and R. Chellappa, "Object detection, tracking and recognition for multiple smart cameras," Proc. IEEE, vol. 96, no. 10, Oct. 2008.

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