Computer Vision Based Vehicle Detection for Toll Collection System Using Embedded Linux

Mr.Abhijeet Suryatali
M. Tech. Student,
Department of Electronics Engineering,
Walchand College of Engineering,
Sangli, India.
suryataliabhijeet900@gmail.com

Mr.V.B.Dharmadhikari
Associate Professor,
Department of Electronics Engineering,
Walchand College of Engineering,
Sangli, India.
vb_dharmadhikari@yahoo.com

***Abstract*—Manyhighway toll collection systems have already been developed and are widely used in India. Some of these include Manual toll collection, RF tags, Barcodes, Number plate recognition. All these systems have disadvantages that lead to some errors in the corresponding system.**

This paper presents a brief review of toll collection systems present in India, their advantages and disadvantages and also aims to design and develop a newefficient toll collection system which will be a good low cost alternative among all other systems.The system is based on Computer Vision vehicle detection using OpenCV library in Embedded Linux platform. The system is designed using Embedded Linux development kit (Raspberry pi).In this system, a camera captures images of vehicles passing through toll booth thus a vehicle is detected through camera.Depending on the area occupied by the vehicle,classification of vehicles as light and heavy is done. Further this information is passed to the Raspberry pi which is having web server set up on it.When raspberry pi comes to know the vehicle,then it access the web server information and according to the type of the vehicle,appropriate toll is charged.This system can also made to count moving vehicles from pre-recorded videos or stored videos by using the same algorithm and procedure that we follow in this paper.

Keywords—Toll Collection System; Vehicle Detection; OpenCV;Background Subtraction;Kalman Filter

I. INTRODUCTION

India is a country where we get to observe most extensive National highways. Government plans various phases to complete the projects under construction. The government signs agreement with the private companies who build the infrastructure like road, port and other stuff for a particular span of time generally in years. The invested amount is charged from the vehicles passing on that newly built highway. This charged amount is called as toll tax. People have no choice to pay for toll tax for using the infrastructure. The private agency involved in the manufacturing of the infrastructure is free to charge citizens. For some places , it is observed that toll tax is still being collected even after completion of contract period.

Initially there were toll collection systems such as manual toll collection without generating computer receipts. This method is really very inefficient. This method of payment was used to stop the vehicles at toll station and wait for relatively long time for their turn to come. This was causing congestion of traffic. The states of congestion and inefficiency prompted government to plan and implement Electronic Toll Collection (ETC) system which can remove out these problems and facilitate convenience for all who involved in the process of toll collection directly or indirectly. ETC systems are designed and developed to cooperate in the operations of toll management through the use of technology. These systems gather data on the basis of traffic, then they will classify the vehicles and collect the expected amount of fare.

Electronic/automated toll collection systems are very popular these days. They do not require manual intervention for their working. There are various methods of ETC in which toll is collected and also various toll booths on which these toll collection systems are implanted. There are many toll collection systems which are present for very long duration still they are collecting toll from people. There is no transparency provided by these systems. Transparent systems play an important role in toll collection such that there will be no corruption regarding toll. The proposed system in this paper is transparent to appropriate toll collection.

II. PRESENT TOLL COLLECTION SYSTEMS

There are following toll collection systems presently used:

A. Manual toll collection

This technique is not a technical method. It requires a toll collector or attendant. The toll collector himself classifies the vehicle, collects the toll, dispense the change, provide receipt to the vehicle owner. All this process is time consuming due to manual intervention. Sometimes,when vehicle comes to booth, toll is charged manually by simply providing just receipt in which no description about vehicle is given, only toll tax amount is present. In this case, what happens, if a heavy vehicle comes to toll booth, Operator charges some amount greater than toll amount of light vehicle but receipt is provided

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for light vehicle. Thus manual collection can provide loss to the owner of booth.

B. RF Tags

In this system, The vehicles are identified with the help of Radio frequencies. RFID stands for Radio Frequency Identification. RFID is a technology which is used to identify, track and store the information contained in the tag. A RF reader scans the tag for data and sends the information to a database contained on the tag.

RFID system consists of two main technology components namely tag and reader.

RFID Tag: An RFID tag, or transponder, consists of a chip and an antenna. A chip can store a unique serial number or other information based on the tag's type of memory, which can be read-only, read-write, or write once read-many(WORM). The antenna, which is attached to the microchip, transmits information from the chip to the reader. Typically, a larger antenna indicates a longer read range.

RFID Reader: In order for an RFID system to function, it needs a reader, or scanning device, that is capable of reliably reading the tags and communicating the results to a database. A reader uses its own antenna to communicate with the tag. When a reader broadcasts radio waves, all tags designated to respond to that frequency and within range will respond. A reader also has the capability to communicate with the tag without a direct line of sight, depending on the radio frequency and the type of tag (active, passive, or semi passive) used. Readers can process multiple items at once, allowing for increased read processing times.

C. Barcodes

This method brings our attention to a new technology for an electronic toll collection. In this system, barcodes are mounted on the number plate of vehicles. The information related to that vehicle is embedded on the barcode. Barcodes are read by the barcode scanners present at toll booths. Thus this method reduces the efforts of human authority. Data information are also easily exchanged between toll authority and vehicle owner, hence providing a more efficient toll collection by less traffic and less possible human errors. But Optical systems at toll booth proved to have poor reading reliability especially when faced with inclement weather and dirty vehicles.

D. Automatic Number Plate Recognition

Automatic number plate recognition is a mass surveillance method that uses optical character recognition on images to read vehicle registration plates. They can use existing closed-circuit television or road-rule enforcement cameras, or ones specifically designed for the task. They are used by various police forces as a method of ETC system on pay-per-use roads and to catalog the movements of traffic or individuals.

Advantages:

- No special tag for vehicle is needed.
- License plates are not likely to be duplicated.
- No chance of interference between adjacent lanes.

Disadvantages:

- The processing algorithms are computation intensive.
- Image processing requires relatively more time and hence multiple readings have slow rate and hence reliability decreases.
- The system is unable to identifyplates due to dirty or damaged license plates, the presence of bumperstickers and similar text on a vehicle, and reduction of visibility caused by rain and fog.
- Low reliability because of the complexity involved in image processing.
- This method typically requires highly reflective license plate.

Disadvantages of Present Systems:

- Manual toll collection is not reliable because any mismatch between toll can be possible through operator.This in turn causes loss to the owner.so he extends the period from government with increased price.Ultimately, common man has no choice to pay toll tax for that period.
- RF tags cannot be implemented on each and every vehicle because it will be very expensive to fit a transponder on each vehicle. This is the major disadvantage of the RFID tag method that it has a major start up expense.
- We need efficient optical system to verify the barcodes. Optical systems proved to have poor reading reliability in inclement weather environment and in rainy seasons especially when vehicles are dirty.
- Number plate recognition is a fully automatic recognition technique. Such systems possess significant error rates which can lead to errors in billing dueto false prediction.

III. TOLL COLLECTION SYSTEM IMPLEMENTED IN OUR PROJECT

The system we present is designed and implemented using an Embedded Linux board called Raspberry pi which is having OpenCV library, Apache server and other necessary softwares installed on it. Basically the system is based on vehicle detection using Image Processing.In this system, a camera captures images of vehicles passing through toll booth thus a vehicle is detected through camera.Depending on the area

occupied by the vehicle,classification of vehicles as Light and heavy is done. Further this information is passed to the Raspberry pi which is having web server set up on it.When raspberry pi comes to know the vehicle,then it access the web server information and according to the type of the vehicle,appropriate toll is charged.

The whole system composes as follows:

A. Embedded Linux

Numbers of commercial OSs are available, but using Embedded Linux is more beneficial as it is open source, stable and reliable, with broad hardware support and moderate requirement of resources. It also has excellent development tools, community supports. Linux is getting tremendous popularity because its open source and some other features like security, scalability, cost, robustness, rate of development. These features can be used in embedded application to make good quality and low cost product. There are lots of development boards available out there in embedded market. Raspberry Pi is one of the popular embedded Linux based development boards.

B. Raspberry pi

The Raspberry Pi is a credit card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools. It is the core of the whole system. The job of Raspberry pi in this system is processing large quantities of data and also it will keep detailed log of vehicles which are in the system.The Raspberry Pi is a good choice for a webserver that will not receive too much traffic and only uses around 5 Watts of power.

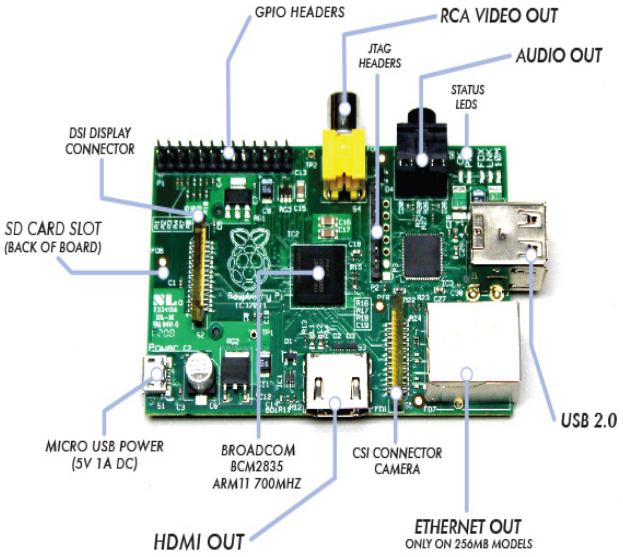

Fig. 1. Raspberry Pi Model B

C. Monitor

Raspberry pi has one HDMI port so that we can connect it to the monitor which is having HDMI cable. It is used to display Graphical User Interface(GUI) of raspberry pi. Also it is used to check the information list of toll collected vehicles. It will help administrator to check whether toll tax is entered correctly or not.

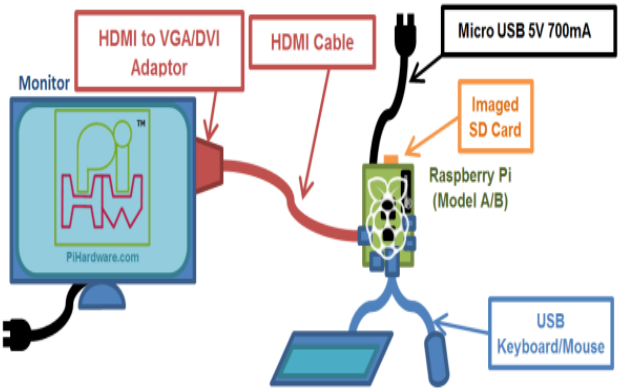

Fig. 2. Connecting Raspberry pi to Monitor

D. Camera

In this project we have to use high image capturing digital camera to get the clear images of vehicles. For practical purpose, we have used following camera just for demonstration.

Fig. 3. iBall Face2Face C8.0 Web Camera used in proposed system

E. Thermal /Dot matrix Printer

It can print copies of the toll to be collected for the customer. Exchanges and refunds also can be run through the system, and a copy of the transaction can be printed when a printer is attached to the system.

IV. SYSTEM DESIGN AND IMPLEMENTATION

In literature survey, we find lots of work on vehicle detection and tracking by using various methods but as compared to it, there has been relatively less work on vehicle classification. The reason might be the classification is inherently hard than detection and tracking. However if we want to classify the vehicles, we first must detect and track the vehicles, as detection and tracking are preliminary steps of classification.

A. VIDEO SUBSYSTEM DESIGN

Vehicles detection must be applicable to different environmental conditions like light, brightness, traffic status changing etc. In our proposed system, while performing experiments we have created a real time scenario. The vehicles are moving on the highway and a camera installed on a toll booth poll is looking down on the traffic scene. This camera captures images of vehicles and provides to the system. These images are nothing but the frames converted from the video by the system.

Further, the system consists of three stages:

1) System Initialization: In the first stage, system gets initialized by camera set up. Camera records continuous stream ofvideo data and sends continuous frames to the system for analysis.

2) Background Subtraction: Background Subtraction is performed on the image framesby using Kalman filter algorithm. In image processing, Kalman filter can be implemented in various ways for different image processing applications. In our project, it is used to extract and maintain background reference image. This background reference image is to be subtracted from the current image from camera to get the desired result of foreground vehicle detection. The background subtraction process is illustrated in fig. 4.

3) Vehicle Detection: In last stage, We have result of background subtraction. Some morphological operations are performed on the result to get the vehicles detected and tracked successfully.

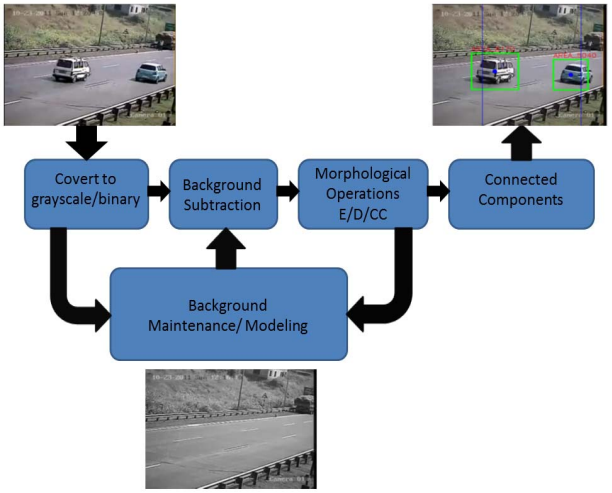

Fig. 4. Background Subtraction

Our system works in real-time camera mode. Real time camera mode application accepts the video from the camera and tracks the vehicles. This system can also made to count moving vehicles from pre-recorded videos or stored videos by using the same algorithm and procedure that we follow in this paper.

A classification system like the one proposed here can give important information for a particular design scenario. Our system uses a single camera mounted on a pole, looking down on the traffic scene at toll booth. It can be used for detecting and classifying vehicles in other different scenario like multiple lanes and for any direction of traffic flow. For such implementation, we just need to provide settings such as camera calibration parameters and direction of traffic for initialization.

B. MOVING OBJECT DETECTION IN OPENCV

OpenCV stands for Open Source Computer Vision. Computer Vision is the transformation of data from a still camera or video camera into a new decision or a new representation. It attempts to provide vision to computer or machine. OpenCV library is designed in C and C++ to increase computational efficiency, supported by almost all operating systems. This library contains the functions more than 500 that deals with real time area.OpenCV has many powerful image processing functions. It focuses mainly on real-time image processing. OpenCV is written in C,C++,Python etc. and its primary interface is in C++.All of the new developments and algorithms in OpenCV are now developed in the C++ interface. So we are using C++ interface in our system.

C. SYSTEM DESIGN

1) Resolution Setting

We are capturing the video stream from web camera so we need to check camera resolution. We make entry of height and width parameters in our coding as per the camera resolution. This application does not produce desired results if they are mismatched. Hence the resolution setting varies as per camera resolution. It is recommended tochange the resolution to 640 x 480 or higher for optimalperformance.

2) Object Detection

Initially the whole system is coded on Ubuntu 14.04 system and afterwards on raspberry pi. Now whatever we are doing on Linux system is going to work on raspberry pi because ubuntu and raspberry pi operating systems are debian based OS provided OpenCV library is installed on both. System is designed to start gettingimages from web camera. Every frame will be processedto find a moving object in the video.

3) Kalman Filter

Kalman filter is a commonly used recursive technique to track linear dynamical systems under Gaussian noise. Kalman filter can be implemented in various ways for background modelling; these implementations differ mainly in state space description of system.

Background modelling is very important in Background subtraction algorithms. Once the background reference image (which is to be subtracted from current image) is extracted, it needs to be updated at regular intervals to compensate significant changes in outdoor scenes, e.g. cloud movements, waves in sea, reflections from water surface, scene illumination etc. But regular updating task might add computational cost to the system.

Kalman filter techniques are known for its computational efficiency, robustness, accuracy and recursive property.Popularity of Kalman filter is due to its above mentioned properties. As the name suggests it filters out noise from measurements.

In image processing, Kalman filter can be implemented in various ways for different image processing applications. In background subtraction algorithm, it can be used to extract and maintain background reference image. It is obtained by applying one dimensional (1D) Kalman filter to each pixel of camera frame of the captured scene.After implementation of 1D Kalman Filter for single pixel, the same concept is extended for all the pixels in a frame. Logic is implemented in OpenCV. Following show results of the application of 1D Kalman filter to all pixels.

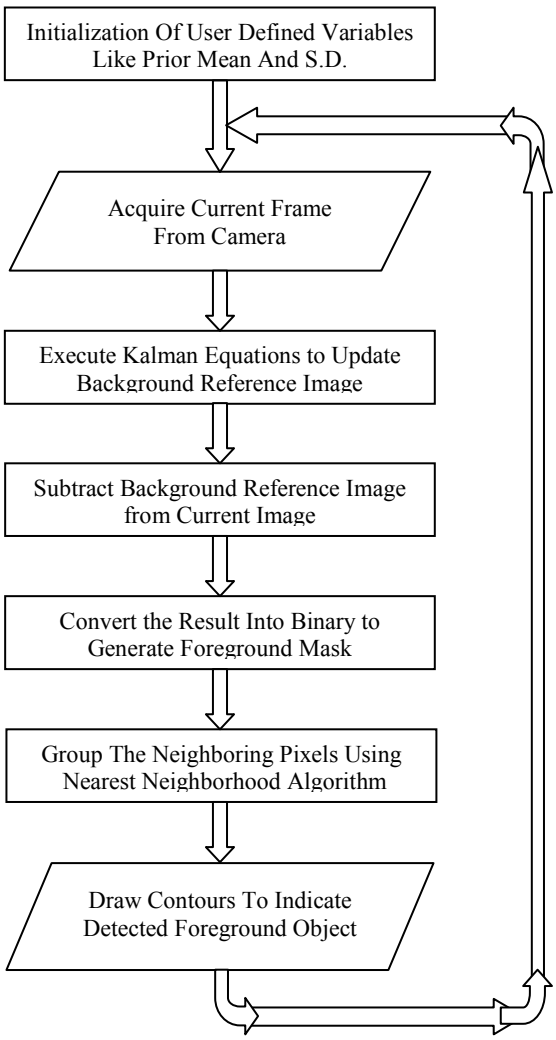

Fig. 5. Procedure of Applying Kalman Filter to image

4) Vehicle counting and classification

After detection, next job is to classify the vehicles. In this work, the detected vehicle regions drawn using OpenCV library functions are classified as light and heavy vehicles. We create a detailed log of vehicles providing information such as how many vehicles were entered and exited; Out of them, how many were light and heavy vehicles in the form of a text file givingfollowing details.

- Entry
- Exit
- Light Vehicles
- Heavy Vehicles

These log files can be stored in particular order on secondary storage device depending upon the date.

V. Experimental Results

We took the results using above system design and implementation on a Dell PC having specifications as an Intel core i5 (3.20 GHZ) CPU and 4GB RAM equipped with iBallFace2Face C8.0 webcam. We tested this system on image frame sequences of the video captured on highway scenes and it is observed that this system is able to detect, track and classify maximum number of vehicles (almost all) successfully. Figures show some results of our system.

Fig. 6. Screenshot of moving input vehicles near toll booth

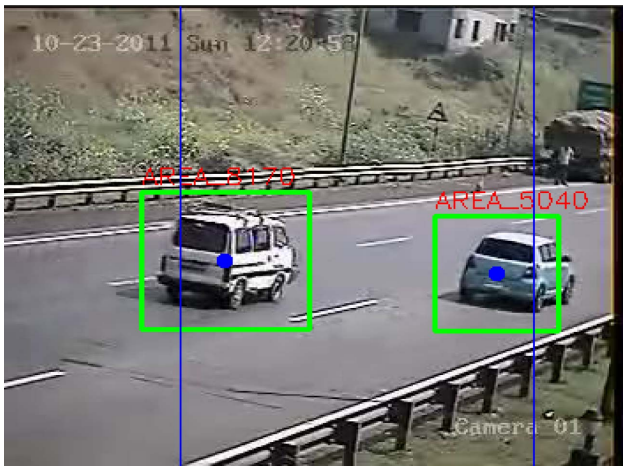

Fig. 7. Screenshot of Detected Vehicles

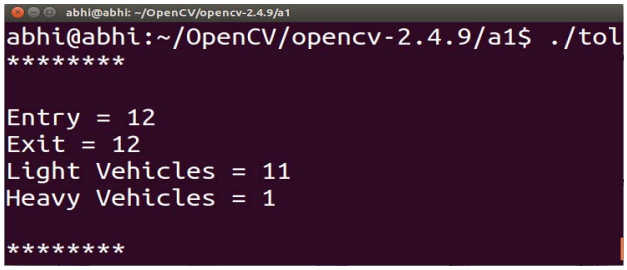

Fig. 8. Screenshot of Printing Summary after Classification of Detected vehicles

VI. Conclusion

Kalman filter is very powerful algorithm as it is robust and efficient enough so that it can be implemented on embedded platform. Robustness of algorithm can be verified from the tests. Results of all these tests are satisfactorily similar; there is hardly any effect of skipping of frames on the output. Tests on algorithm suggest that the threshold of variance between foreground and background is crucial parameter to look for. Embedded Linux platform is very useful for implementing different aspects of the proposed system. Ubuntu OS provides very powerful interface between Open CV and lower level peripherals like GPIOs; so embedded hardware can be controlled from image processing programs written using Open CV.

References

[1] Uke Nilesh J., and Ravindra C. Thool. "Moving Vehicle Detection for Measuring Traffic Count Using OpenCV." Journal of Automation and Control Engineering Vol 1.4 (2013).

[2] Kamalakannan, P., et al. "Automated toll collection with complex security system." Education Technology and Computer (ICETC), 2010 2nd International Conference on. Vol. 4. IEEE, 2010.

[3] KRaihan, Kawser Jahan, et al. "Raspberry Pi Image Processing based Economical Automated Toll System." Global Journal of Researches In Engineering 13.13 (2013).

[4] Juan, Zhang, and Xu Jianjun. "Research of overall program on highway toll collection system." Information Science and Technology (ICIST), 2011 International Conference on. IEEE, 2011.

[5] Persad, Khali, C. Michael Walton, and Shahriyar Hussain. Toll Collection Technology and Best Practices. No. Product 0-5217-P1. 2007.

[6] Li, Shuguang, et al. "Video-based traffic data collection system for multiple vehicle types." IET Intelligent Transport Systems 8.2 (2013): 164-174.

[7] Buch, Nobert Erich. Classification of vehicles for urban traffic scenes. Diss. Kingston University, 2010.

[8] Pietrzyk, Michael C., and Edward A. Mierzejewski. Electronic Toll and Traffic Management (ETTM) Systems. No. Project 20-5 FY 1992. 1993.

[9] Scott, J.; Pusateri, M.A.; Cornish, D., "Kalman filter based video background estimation," *Applied Imagery Pattern Recognition Workshop (AIPRW), 2009 IEEE* , vol., no., pp.1,7, 14-16 Oct. 2009 doi: 10.1109/AIPR.2009.5466306

[10] Robert, Kostia, "Video-based traffic monitoring at day and night vehicle features detection tracking," *Intelligent Transportation Systems, 2009. ITSC '09. 12th International IEEE Conference on* , vol., no., pp.1,6, 4-7

Oct.2009
doi: 10.1109/ITSC.2009.5309837

[11] Hsieh, Jun-Wei; Shih-Hao Yu; Yung-Sheng Chen; Wen-Fong Hu, "Automatic traffic surveillance system for vehicle tracking and classification," *Intelligent Transportation Systems, IEEE Transactions on* , vol.7, no.2, pp.175,187, June 2006
doi: 10.1109/TITS.2006.874722