Internet of Things (IoT)

Technologies, Applications, Challenges, and Solutions

Edited by B.K. Tripathy • J. Anuradha

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To my wife, Sandhya, for her untiring effort and constant support, which have helped me in my research endeavors in a big way.

— B.K. Tripathy

To my Teachers, Family, and Friends whose impression cannot be washed away from my life.

— J. Anuradha

Contents

Preface

Internet of Things (IoT) is the third wave of Internet and is supposed to have a potential to connect about 28 billion items by 2020, ranging from bracelets to cars. The term "IoT," which was first proposed by Kevin Ashton, a British technologist, in 1999, has the potential to impact everything from new product opportunities to shop floor optimization to factory worker efficiency gains that will power top-line and bottom-line gains. It is believed that IoT will improve energy efficiency, remote monitoring, and control of physical assets and productivity through applications as diverse as home security to condition monitoring on the factory floor. Now IoT has been used in markets in the field of health care, home appliances and buildings, retail markets, energy and manufacturing companies, mobility and transportation, logistics companies, and by media.

Equipments are becoming more digitized and more connected, establishing networks between machines, humans, and the Internet, leading to the creation of new ecosystems that enable higher productivity, better energy efficiency, and higher profitability. Sensors help to recognize the state of things, by which they gain the advantage of anticipating human needs based on the information collected per context. These intelligent devices not only gather information from their environment but are also capable of taking decisions without human intervention. IoT technology is being used in our day-to-day life for unlocking the door without a key; in card recognizers, automatic locks, vehicle detecting systems, toll payment system; and for tracking animals, access control, payment systems, contactless smart cards, anti-theft devices, steering column reader, etc. The IoT building blocks will come from those that are web-enabled devices, providing common platforms on which they can communicate, and develop new applications to capture new users.

In this background, this book is an attempt to present updated information on the recent trends on the issues involved, highlighting the challenges involved, and source the solutions for some of these challenges. The book comprises 14 chapters. The chapterwise description of contents in the volume is as follows.

For seamless visual tracking of passengers traveling in a vehicle, the visual light transmission (VLT) and visual light reflectance (VRT) values of the glass windows used in the vehicle should be at a particular value. All vehicle manufacturers follow certain standards. But the vehicle owner/user generally buys window-tinting films from the gray market and pastes the same on the glass windows, which in turn hamper the visibility, thereby preventing the law enforcement authorities from having a clear view of those traveling in the vehicle. In Chapter 1, a proposal for the automatic detection of tint level for vehicles is presented. The system has been designed using ordinary cameras that work in the visible region of the electromagnetic spectrum. The system is capable of identifying a vehicle's registered number using algorithms developed for this purpose. Various filtering techniques are applied to find the level of tint from the captured camera images. Using three different techniques, namely, color segmentation, contour detection, and histogram analysis, the tint level of windshield/window region is estimated. Thus, the IoT system recognizes the numbers on the number plate and can fetch the contact details of the owner from the database. It also communicates the same information to the owner with details on and extent of tint level violation along with documentary evidence.

Supervised and unsupervised learning techniques are reliable tools for the classification and categorization of data. Wearable devices are a relatively recent consumer technology that record large amounts of data by measuring signals around the body. Wearables come in several forms, such as wristbands, armbands, watches, and headbands. Chapter 2 explores the use of supervised and unsupervised learning techniques to identify individuals and activities using a commercially available wearable headband. It also deals with applying machine learning techniques for identifying individuals and their activities that are recorded through various wearable devices available in the market. A deep review on various algorithms applied for sensor data generated by wearable devices is carried out. Supervised and unsupervised learning algorithms are applied on EEG brain signal data for classification. This chapter also discusses challenges involved in handling sensor data and its mining.

IoT is a prototypical example of big data. In order to have viable solutions to that effect, artificial intelligence (AI) techniques are considered to be the right choice. Hence, the IOT system with AI techniques makes us to have smart applications like smart e-health, smart metering, and smart city to name a few. Although IoT is gaining everybody's attention today, security aspects need to be effectively addressed to prevent an intruder from causing disastrous consequences. In Chapter 3, the problem of prediction of energy consumption data generated through the smart grid step to connect all power grids for efficient energy management is discussed. The system applies convolution neural network and addresses the challenges posed by the IoT datasets and is considered to have widespread applications in the future digital world. The system is checked against publicly available smart city, smart metering, and smart health.

Due to enormous growth in the various applications of IoT, it has the potential to replace people as the largest producer and consumer of the Internet. The integration of wireless communication, microelectromechanical devices, and Internet has led to the development of things in the Internet. It is a network of network objects that can be accessed through the Internet, and every object connected will have a unique identifier. The increasing number of smart nodes and constant transfer of data are expected to create concerns about data standardization, interoperability, security, protection and privacy, and other issues. Chapter 4 elaborates on the technical, societal challenges and the impact of IoT applications. With the increasing number of smart nodes and constant transfer of data, it is expected to create concerns about data standardization, interoperability, security, protection, and privacy. This chapter gives a detailed outlook at the issues related to software engineering and security in IoT, from which one can provide solutions based on its understandings.

The social Internet of things (SIoT) is an emerging topic of the digital era with social, economic, and technical significance. The IoT has already proved its dominance in a wide range of sectors such as consumer products, durable goods, transportation, industrial and utility components, and sensors. It is now extended to social media. The evolution of powerful social network data analytic capabilities transforms the social livelihood into a new era of link prediction, community grouping, recommendation systems, sentiment analysis, and more. Chapter 5 covers the evolution of powerful social networking using IoT. The present society is digitally progressing toward an ever connected paradigm. It explains the basics of IoT and its technological evolution. The popularity of social networking describes the emergence of social network analytics in IoT. This chapter further discusses various security issues and research challenges pertaining to IoT analytics. It also provides information and references for further research and developments in applications for those in pro-business and pro-people social IoT services.

It has been established that a habitual typing pattern is a behavioral biometric trait in biometric science that relates to the issues in user identification/authentication systems.

Nevertheless, being nonintrusive and cost-effective, keystroke dynamics is a strong alternative to other biometric modalities. It can be easily integrated with any other existing knowledge-based user authentication system with minor alternation. Obtained accuracy in previous studies is impressive but not acceptable in practice due to problems in intra-class variation or data acquisition techniques. Chapter 6 deals with the prediction of authenticated user depending upon the individual typing pattern. The system aims to identify the user through the data generated based on the typing style. It also identifies the age, gender, ingenuity, and typing skills. A hybrid fuzzy and rough technique is being used and has proved to be effective.

Nanotechnology plays an important role in changing the world through the development of new technologies in various fields such as health care, manufacturing, agriculture, and industrial control systems. Recent developments in the Internet of Nano-Things (IoNT) are instrumental in the production of new nano devices. In Chapter 7, recent trends in nanotechnology are discussed and its roles in various emerging fields are presented. This chapter discusses the challenges and opportunities for the Internet of Forensic Nano-Things (IoNTF) in assisting and supporting reliable digital forensics in the IoNT environment.

Most devices we use today are equipped with sensors that have the capability of communicating and acquiring intelligence. Advancement of such technology supports mankind to assist in daily chores. Ambient assisted living (AAL) has drawn attention from people who are dependent, aged, and are under care. Chapter 8 focuses on this interesting application of IoT, that is, AAL. AAL systems are IoT-enabled that are exclusively designed to assist the aged/senior citizens in their daily activities. This chapter discusses various types of sensors used for this purpose and their strengths and weaknesses. It also describes various approaches adopted to develop an AAL system. Software engineering–based model development in AAL will enhance the functionality of the system, which is crucial in handling emergencies that older people encounter.

IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human-to-computer interaction. Here, we need to know how the devices or things in IoT are communicating and how the name service will translate the meaningful names to machine-understandable form. Chapter 9 discusses the role of the naming service and the high-level requirements of the name service in IoT. It elaborates on the middleware technology to support device naming, application addressing, and profile storage and look-up services in IoT environments. Challenges of naming services in IoT are discussed along with how naming, addressing, and profile server (NAPS) overcomes these challenges. Platform-independent NAPS is discussed in detail with its complete design, including its functionalities, system flows, interfaces, etc.

Generally, an IoT application focuses on timely service and improves the efficiency. With this reason, today many IoT-based healthcare medical devices have been developed to provide proper treatment for patients in a timely manner. In the medical field, such devices have adopted the principle of lightweight protocols to communicate between various IoT-based medical devices. Chapter 10 provides information about recent technologies to mitigate security issues in IoT health care. This chapter discusses various security protocols and standards, concentrating on a detailed study of the security issues in communication among the devices. It offers a simulated approach and provides solutions to security using elliptic curve public key cryptography, which is implemented in a step-by-step manner in Contiki network simulator (Cooja) simulator.

The security issues in many IoT implementations, although already present in the field of information technology, offer a lot of unique challenges. It is a fundamental priority to address these challenges and ensure that the IoT products and services are secure. Chapter 11 deals with the challenges involved in handling security issues on IoT data. IoT devices are vulnerable to attacks as the systems have a very low level of protection and security. In this chapter, several types of intrusions and threats in IoT are discussed. An innovative framework to develop a secured system along with authentication is proposed. The collaborative learning approach has proven to be an ideal model in recognizing the pattern of the intruder, and the system can provide a solution based on it.

Diseases occur because of the interaction of agent, host, and the environment that is altogether called the "epidemiological triad." There are numerous reasons for the failure to prevent the complications of diseases. Physicians address only the biomedical part of the disease and ignore the other important aspects due to lack of experience and time. This need not remain so, provided the science of diseases and the art of healing by physicians are embedded in wearable computational devices. Chapter 12 addresses the electronic health record maintenance by coupling IoT devices with the system where the medical practitioner can view the data on the table. It also emphasizes that IoT is a boon to the medical field that saves doctors' time in handling other necessary calls. Wearable devices like fever watches when used on babies will reduce the risk of diseases by regular monitoring of the sensor data. The goal of this chapter is to make use of IoT to place health in the hands of the patients, which is one of the key principles of primary health care.

Billions of devices are expected to be connected to the Internet in the near future. This will provide interoperability among the things on the IoT which is one of the most fundamental requirements to support object addressing, tracking, and discovery, as well as information representation, storage, and exchange. Defining ontology and using semantic descriptions for data will make it interoperable for users and stakeholders that share and use the same ontology. Chapter 13 provides an overview of semantics in IoT-based analytics. This chapter briefs on semantic technology and its specifications and deployment to develop an application on smart systems.

Autism spectrum disorders (ASDs) show the concepts of instabilities that are disturbing social communication, interaction, and normal behavior in general. Every autistic child is unique in a way. They face severe problems with emotional balance, communal interactions, and communication skills. Such conditions necessitate a high degree of personalization to communicate with the outer world. Today, medical science has not been able to trace the exact reason for autism, but most therapists have proved that it is unpredictable behavior of neurons in human brains. We require a unique set of tools and methodologies to train autistic children. It requires enhancing the intensity of awareness about existing and narrowed competence among autism children to discover the way that unaffected children are performing. In Chapter 14, classification of the opportunities and trends of IoT applications and solutions for autistic children are presented. Also, from an IoT application perspective, diversified smart technologies like wearable environmental sensors mobile apps, home appliances, and others are discussed. The motivation of this chapter is to discuss the prospect of availability of an IoT support and in availing the services for enhancing the lives of autistic children and their supporting families in the society. Also, it helps to teach and train autistic children the basic skills and concepts in their day-to-day requirements.

IoT challenges for the future include ubiquitous data collection, potential for unexpected use of consumer data, and heightened security risks. So, the current technology needs to be improved to enhance privacy and build secure IoT devices by adopting a security-focused approach, reducing the amount of data collected by IoT devices, increasing transparency, and providing consumers with a choice to opt out. In an effort to draw the various issues in IoT, challenges faced, and existing solutions so far, the chapters of this volume have been meticulously selected and studied by knowledgeable reviewers.

It is the wish of the editors of this volume that this effort of theirs in accumulating so many challenges faced in the field of IoT, which have been focused on in the various chapters of this volume, will be helpful for future research in this field. Specifically, the real-world problems and different application areas presented will attract the attention of the researchers in the field and provide them with valuable input.

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Also, many colleagues and friends have helped in some way or other. We wish to thank them all.

Editors

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IoT-Enabled Vision System for Detection of Tint Level

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1.1 Introduction

In a typical automotive system, such as cars, buses, and lorries, we use glass windows at many places. The purpose of the glass window provided at the back side is to provide clear visibility of vehicles that are approaching our vehicle. The glass window provided at the front side of the car (called windshield) gives a clear view of things ahead of our vehicle. The driver moderates the speed of the vehicle according to the objects seen through the windshield. At every row of passenger seats, depending on the type of the vehicle, glass windows are provided on either side. The purpose of these glass windows is to give visibility of outside world to the passengers while traveling. During accidents or emergency situations, one can even break these windows and escape out of the vehicle. Apart from this, a mirror has been provided near the driver seat. Using it, a driver can look at the approaching vehicle(s) and also roughly estimate their speed which in turn will help him to take proper decisions on how to maneuver the steering wheel and avoid accidents.

The law enforcement authorities such as police personnel can look through these glass windows from outside and find out who are all traveling inside the vehicle. This kind of tracking is normally done by police personnel whenever some untoward incident such as accident or bomb explosion happens. In many such untoward incidents, typically the criminals/extremists escape in the vehicles to remote locations. Then, the police personnel are forced to track all vehicles at many strategic locations to identify or find where the criminals are. This kind of tracking is possible only if the police personnel are able to see the driver/passengers who are traveling in a vehicle from outside.

For seamless visual tracking of passengers traveling in a vehicle, the visual light transmission (VLT) and visual light reflectance (VLR) values of the glass windows used in the vehicle should be at a particular value. All vehicle manufacturers follow certain standards. But the vehicle owner/user generally buys window tinting films from grey market and pastes the same on the glass windows which in turn will hamper the visibility, thereby preventing the law enforcement authorities from having the clear vision of those traveling in the vehicle. In many cases, the tinting films are such that the passengers traveling inside the vehicle can clearly see the outside world through the glass window while the outsiders may not be able to see who are all inside the vehicle. To regulate this, law enforcement authorities in each country/state have prescribed certain threshold values on the VLT/VRT value to be used after fixing the tinted films on the glass window.

In this chapter, we propose a video-based automatic technique that will not only identify the vehicle (say, car) but also estimate the VLT percentage. If the VLT level is below the prescribed limit (say, 35%) then the envisaged system will automatically identify the vehicle number plate. Then the identified vehicle registration number will be searched in the appropriate database to locate the violator's contact details. Subsequently, an automatic message will be transmitted to the concerned person along with the date, time, and place of violation. Thanks to IoT (Internet of Things), the proposed system not only identifies the tint level violation but also provides documentary evidence and communicates the same to the relevant person.

1.2 Literature Survey

"Window tinting" refers to the methods used to block certain levels of light from passing through the glass window of vehicles. Most of the window glasses in the vehicles are coated or treated in order to filter the harmful ultra-violet (UV) rays entering the vehicle. The window tinting has various other effects. (1) Dark tinting will reduce driver's vision, particularly while driving at night. (2) Tinting windows will distort the vision of aged people and people with problems with eye sight. (3) If anyone wears polarized sunglasses, it will produce some visual patterns on the window. (4) Over a period of time, tinting can even lead to bubbles, peel, or develop cracks that may bring down the value of a vehicle and it general look. (5) Many vehicles come with window glasses that are engineered in such a way that in the event of an accident, they will "break away." At times, the tinting material will prevent windows from breaking during accidents. This in turn can cause or even worsen injuries during accidents.

Computing systems are generally introduced wherever speed and accuracy is needed. A typical computing system works on the principle of input–process–output. In the conventional computing system, the input is keyed in by human beings (as we see in many reservation counters, banks, etc.) and the software algorithm running at the computing system processes the inputted data and produces an output. In general, these outputs are displayed on a display device such as a monitor or printed using a printer. If people responsible are lethargic or lazy, often the speed and accuracy of the computing system is lost. However, IoT systems help us to resolve this issue.

In the case of an IoT system, the inputs are replaced by relevant sensor(s). Hence, the possibility of human errors can be eliminated to a great extent. Whenever we use a vision-based IoT system, the camera acts as an input sensor. Unlike a computing system, the processing application is located at a central server (or cloud system) in the case of an IoT system. In many IoT systems, the sensors forward their data to a local computing system via short-range wireless communication protocols such as Bluetooth, Zigbee, and WiFi. The local computing system preprocesses it and sends it to a central server (cloud) at regular intervals using long-range wireless communication protocols such as SMS, 2G, 3G, 4G, and WiMax. The central server (cloud) software collates the data and takes some informed decision (generally using analytics) and sends it back to the local server/end user. But in the case of an IoT system, one uses an actuator (controlling a valve) or an event driver notification system (such as an SMS/e-mail alert in a mobile phone). Thus, an IoT system uses sensor–processor–actuator principle. This can bring in next level of automation in many industries. The important challenge in IoT is designing proper sensors, actuators, and interfacing with wireless communication protocols. In general, the data handled by the servers are unstructured.

Thus, a typical IoT-enabled system consists of sensors, embedded system, (wireless) communication, data storage via Internet into a cloud server, an analytics software system to take informed decisions at the cloud platform, and an optional receiver end device (mobile). In few cases, the receiver end system will be an actuator that will execute certain actions on the targeted hardware. We can choose appropriate object(s) (such as lockers, curtains, consumer electronics devices such as cookers) and interface it (them) with an appropriate sensor(s). The embedded system attached with the object can sense the required data and monitor it continuously. At periodic, pre-defined time intervals, the necessary data are transfer to a remote location for storage using wired or wireless communication protocols (such as UDP, TCP/IP, Wi-FI, Bluetooth, ZigBee). The data aggregated from various objects are stored in the server, preferably a cloud server. At periodic intervals, the aggregated data are analyzed/diagnosed using appropriate analytics software running in the server (cloud). The decisions are informed accordingly to the end user/system. In most cases, it turns out to be the notification in the mobile device or actuation of some subsystems of the end device (such as rotating a fan, opening the valve system, switching ON/OFF).

Currently, there are many devices to measure the VLT/VRT values, called tint meters. There are two popular types of tint meters available in the market, namely one-piece tint meter and two-piece tint meter. The one-piece tint meter is used to check the tint level of side (glass) windows. If we use the one-piece tint meter, then one has to request the driver of the vehicle to be inspected to stop the vehicle and ask the driver/passenger to roll down the (side) windows partially. The tint meter has a slot built in to it (as shown in Figure 1.1). One has to insert the partially opened window into this slot and by pressing a button the light waves of specific wavelength are transmitted from one side of the tint meter and a receiver at the other side of the tint meter will analyze the received light waves. Depending on the transmitivity/opacity of the glass along with the black film pasted on it, we get values ranging from 0% (opaque material such as card board) to 100% (for pure air). Generally, the lighter glasses have high transmittance (65% to 80%) and the darker glasses have low transmittance (20% to 35%). In many states/countries, the allowed transmittance level is 35%. If the vehicle's glass tint level goes below this level, then one can issue a ticket and initiate legal action.

In the case of two-piece tint meters, we have two pieces, one back meter and one front meter (as shown in Figure 1.2). These kind of tint meters also are used to measure the

FIGURE 1.1
One-piece hand-held tint meter.

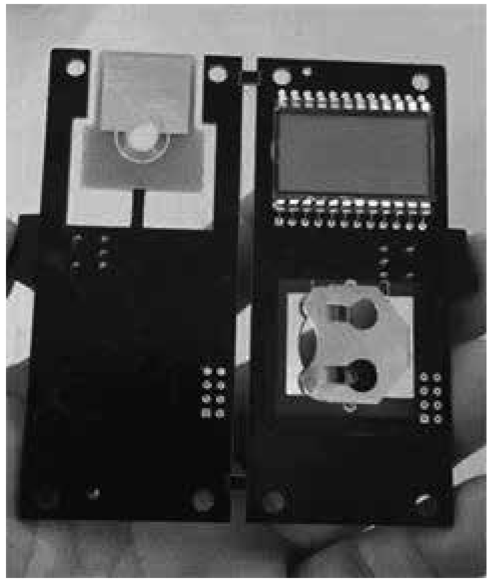

FIGURE 1.2
Two-piece hand-held tint meter.

tint level of glass windows used at the front side (wind shield) and rear (back) side of the vehicle. One can also use them for measuring the tint level of side windows of vehicles. The back meter is attached at the back side of the glass. It has a suction cup so that it can firmly stick to the glass window. The front meter is attached at the front side of the glass to be tested. The magnet helps both the pieces to be held together. By pressing a button, we can get the exact light transmittance value.

The main problem in both these types of tint meters is that one has to stop the suspected vehicle and carry out the experiment. We would like to design an IoT-enabled vision system that can resolve this problem. That means with our proposed system, we can measure the light transmittance value of glass windows of vehicles when it is moving. Our approach is based on image/video processing techniques. In our proposed method, we first extract vehicle windshield region using Gaussian kernel–based background subtraction, histogram equalization, optimal edge detection, and extreme point detection techniques. Then, in the detected region, we estimate the tint and transparency level. If the vehicle violates the government norms, then we crop the number plate and locate the owner's communication address and generate a ticket automatically by attaching the evidence.

1.3 Overview of the Proposed Methodology

Figure 1.3 shows the overview of the proposed windshield tint level detection system based on real-time vision. The input to our system is a live video captured through surveillance camera. From the captured video, two frames are extracted; one is the background image (taken when no vehicle is moving) and another one is the foreground image (taken when the vehicle is moving). Both the images have certain common properties such

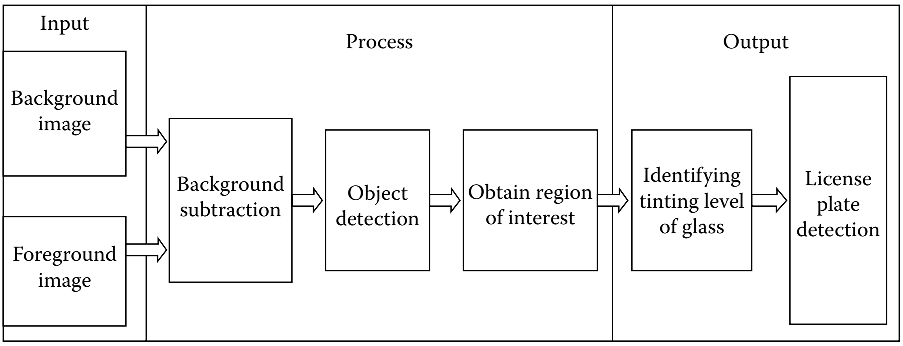

FIGURE 1.3
Overview of the proposed windshield tint level detection system based on real-time vision.

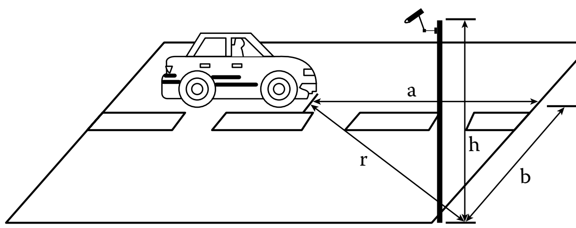

FIGURE 1.4
The operational environment of the proposed system.

as image color, image position, image size, image type, and origin. The images are initially preprocessed. The preprocessing includes filters, brightness and contrast equivalization, and image conversion. Using adaptive background subtraction method, the foreground object (moving vehicle) is only extracted. From this processed image, the region of interest (ROI), namely windshield/window region, is extracted, and then this ROI is cropped from the original color image and is passed on to the tint level calculation module. Three different techniques of tint detection were employed in the present work. If the tint level exceeds the prescribed limits, then the process switches over to license plate detection to uniquely identify the vehicle, and a ticket is issued, if necessary.

Figure 1.4 shows the operational environment of the proposed system in which the camera is placed at a certain height h from the ground level. The height is generally about 8–10 feet above the ground level so that the windshield/window can be easily visible with desirable coverage area that can also easily locate the number plate of the vehicle, if necessary. While capturing the image, the vehicle is in a position such that "r" is the shortest distance from the base of the pole on which the camera is mounted on the roadside and the front end of the vehicle. Here a and b are the horizontal and vertical components of this distance r, respectively. The camera inclination position should generally be not more than 30° with respect to the windshield/window level so that the internal view of the captured image (vehicle internal view) will be good.

Figure 1.5 shows the methodology used for finding the distance of the vehicle from the camera which in turn can be used for classifying the vehicle. For this purpose, the ground region is segmented into various imaginary grid lines both along x- and y-axes (x_1, x_2,… and y_1, y_2, y_3,…) and is overlaid on the captured image. Assume that the vehicle is present

FIGURE 1.5
Distance calculation using overlaid coordinates on the acquired image.

at the segmented graph location denoted as (x_{25}, y_{21}). Let the length and breadth of each block in the segmented graph be fixed. Then, the horizontal component gives the value "25 (from x component) * length of block" and the vertical component gives the value of "21 (from y component) * breadth of black." From these horizontal lengths and vertical breadths, one can calculate the aspect ratio, to approximately classify the vehicle type. Identification of vehicle types is very important in our case. The number of windows and location of windows depend on the type of vehicle.

1.4 Implementation Details

Figure 1.6 shows the detailed adaptive background subtraction (ABS) algorithm implementation. Here, two images, that is, background (Bg) and foreground (Fg) images are given as input to the system, and an appropriate filtering algorithm is applied to both the images for removing the noises (if any) from the images. Then, the images are converted into gray-scale images and their corresponding histograms are equalized for the desired background subtraction. The whole process is performed by pixel-by-pixel comparison of foreground and background images. If the absolute difference value of the foreground image pixel and its corresponding background image pixel is greater than a specified threshold value, then it is considered as foreground image and hence it is substituted with a high-intensity value (say, 255), else it is substituted with a low-intensity value (say, 0). Along with this subtraction process, the updation of background image is also done by comparing the foreground and background image pixels. This updation is performed to change the background image according to the change in environment. In this comparison, if the background image and foreground image intensity of specific location is the same, then the background remains same (no updation). Otherwise, if the value of the background pixel intensity of a specific location is greater than the value of the foreground pixel intensity of the corresponding location, then the background pixel intensity value is increased by one, if not the intensity value is decreased by one.

In Figure 1.6, an image "I" consists of a finite set of pixels and our mapping assigns to each pixel p = (Px, Py), a pixel value $I(p)$. Consider that the mapping is done in Z^2 plane. So, in this algorithm, we have two images; one is background image which is represented as "Bg" and its intensity value Bg(p) which is mapped in Z^2 plane at p = (Px, Py), and the

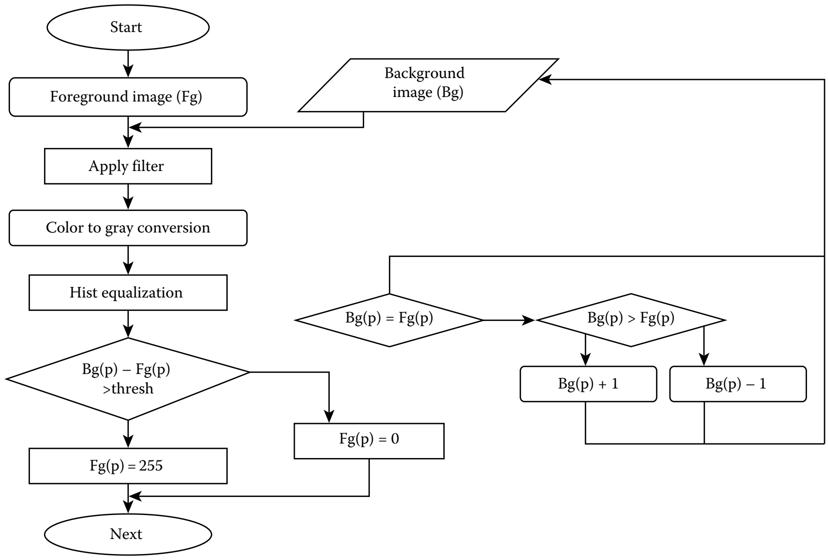

FIGURE 1.6
Data flow diagram explaining the adaptive background subtraction algorithm.

other is foreground image which is represented as "Fg" and its intensity value Fg(p) is also mapped in Z^2 plane at p = (Px, Py). The mapping of both images is the same because they have the same property.

1.4.1 Noise Removal

Most of the dynamic scenes exhibit persistent motion characteristics. Therefore, in order to reduce noise, image must be preprocessed with an appropriate filter. In our case, we used Gaussian kernel filter. Gaussian filtering is done by convolving each point in the input array with a Gaussian kernel and then summing them all to produce the output array. Gaussian kernel for N (N = 1, 2, 3,…) dimension is given by

$$G_{\mathrm{ND}}(\bar{x};\sigma) = \frac{1}{\left(\sqrt{2\pi}\sigma\right)^N} e^{-\frac{|x|^2}{2\sigma^2}} \tag{1.1}$$

Here, σ determines the width of the Gaussian kernel. In statistics, when we consider the Gaussian probability density function, it is called the standard deviation, and the square of it namely, σ^2, is called the variance. The normalized Gaussian kernel has an area under the curve of unity, that is, as a filter it does not multiply the operand with an accidental multiplication factor.

The output of Gaussian filter is converted to a format (image format) which is easy to process. For this purpose, we use gray-scale range of shades wherein the darkest possible shade is black, which is the total absence of transmitted or reflected light and the lightest possible shade is white, which has the total transmission or reflection of light at all visible wavelengths. Intermediate shades of gray are represented by equal brightness levels of the three primary colors (red, green, and blue) for transmitted light, or equal amounts of the three primary pigments (cyan, magenta, and yellow) for reflected light.

1.4.2 Adaptive Background Subtraction

After preprocessing, the main task of background subtraction is to find d which is defined as $d(p) = |\text{Fg}(p) - \text{Bg}(p)|$. Here, Fg refers to foreground image, and Bg refers to back ground image. "p" refers to the position of various pixels on the image. Thus, d(p) refers to the distance between foreground and background image pixels. This difference must maintain the value less than the threshold value which is determined by the user. We store the $d(p)$ value in a visual pattern which is done by creating a matrix of size similar to foreground image which we call as "abs image." If the $d(p)$ is below a definite threshold value, then the "abs" image is padded with lowest intensity value and if $d(p)$ goes beyond the definite threshold value, then the "abs" image is padded with the highest intensity value. The abs image gives the subtraction of background and foreground image. Now we need to change the background image according to the change in the environmental or dynamic road condition such as a vehicle. It checks the background frame and verifies whether there is any change in the background image with respect to the foreground image. If $\text{Bg}(p) > \text{Fg}(p)$ for the location p, then the background intensity $\text{Bg}(p)$ is added with some arbitrary value, that is, "$\text{Bg}(p)$ + value" and if $\text{Bg}(p) < \text{Fg}(p)$, then $\text{Bg}(p)$ is subtracted with the same arbitrary value, that is, "$\text{Bg}(p)$ – value," and if $\text{Bg}(p) = \text{Fg}(p)$, then no change is done on the background image.

Our next intention is to increase the global contrast of foreground and background gray-scale images, especially when the usable data of the image is represented by the nearest contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

1.4.3 Object Detection

The processed image ("abs" image) now contains high-intensity levels (which corresponds to the foreground and background intensity difference) indicating the presence of an object (i.e., vehicle). Then, we apply morphological operations on this processed image. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. The shape and size of the structural element is used to remove imperfections added during segmentation.

Figure 1.7 shows the auto-cropping algorithm used for obtaining the ROI from the chosen input foreground image. The algorithm is performed on the black and white images obtained from the background subtraction algorithm, and from this image one can identify the pixel location values for cropping the vehicle from the given foreground image. Initially, the size of image is stored in two variables, in which one is used to define the row size (say, row) and the other is used to define the column size (say, col). Now the variables m and n are set such that they store the starting location, namely top left corner of the image [say, $p(1,1)$] and bottom right corner of the image [say, p(row, col)]. We look for the first transition from low to high-intensity value of pixels from all sides (top, bottom, left, right) of the image. By scanning the binary image

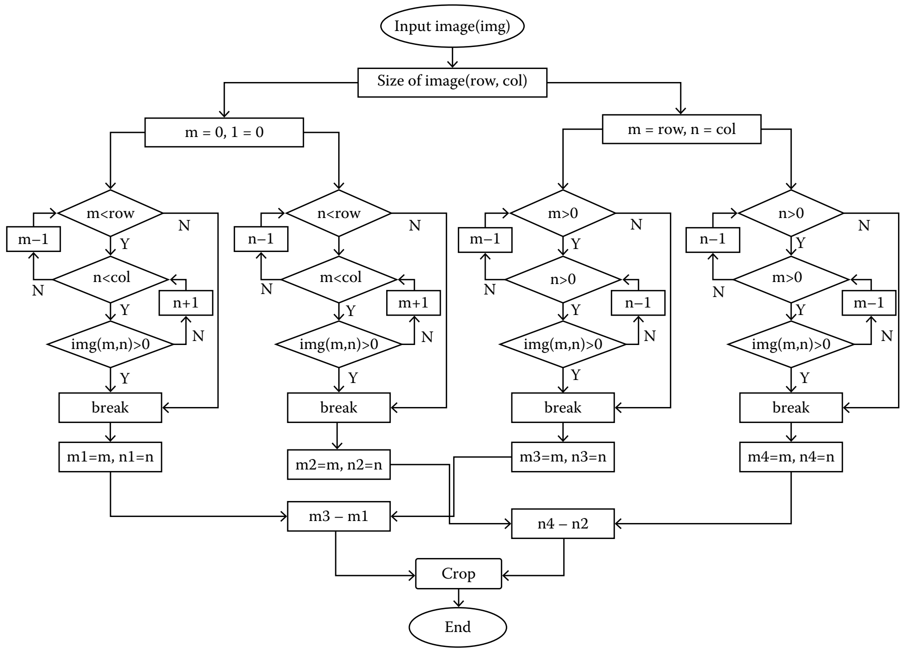

FIGURE 1.7
Data flow diagram for finding regions of interest and cropping the objects of interest.

from top to bottom and from left to right, we locate the extreme points (pixel locations) [say, top left pixel (m1, n1), top right pixel (m2, n2), bottom left pixel (m3, n3), and bottom right pixel (m4, n4)]. From these four extreme points, we can find the height and breadth of the vehicle which can fit into the rectangular box. Using these parameters (pixel extreme locations, length and breadth) on the original color image frame, we can crop the vehicle portion alone.

From the ROI, we can find the ratio of height and width of the vehicle which is directly related with the width and breadth of image rectangle. From this obtained ratio, the type of vehicle is determined such as hatchback or notchback (sedan class). The windscreen/window area generally changes according to the type of vehicle. For example, in the sedan class vehicles, the windscreen location is nearly at the middle whereas in hatchback vehicles, it is slightly at the rear side of the vehicle. Thus, the vehicle tint location can be easily obtained for different class of vehicles. Once the vehicle class/type is extracted, then we can extract the windshield/window tint area of the vehicle and on this cropped area we apply our three basic techniques of tint detection, namely contour detection, histogram analysis, and color segmentation.

1.4.4 Tint Level Detection Algorithm

The first technique is color segmentation which identifies different color percentages present in the windshield/window area of the extracted image. It is also beneficial to identify approximately which color tint is applied on the screen on the basis of color percentage of different channels. In the present technique, the three channels of extracted area are separated out (i.e., RGB channel). In the separated channel, a specific point is defined for finding the intensity level in the image. For better accuracy, two or more points are identified within the window region and the average intensity of the pixels is used. Then, this intensity value is represented by their intensity percentage. According to the database available for VTL percentage for different environmental conditions, the approximate tinting level is determined. Table 1.1 shows the various tinting level on green/blue channels and the corresponding RGB level of region in the image.

The second technique used is known as contour detection which improves the tint detection of windscreen/window of vehicle. Contours can be explained simply as a curve joining all the continuous points (along the boundary), having the same color or intensity. In this technique, first we find the edges of the image by using relevant edge detection technique. After edge detection, the image becomes a function of two variables which are curves joining all continuous points, and these curves are called contours. These contours are in different numbers depending on the reflection of light through windshield/window glass. The number of contours is counted in the given image. From the available database (calculated manually) of contour for various intensity levels, the threshold (here is the number of contours) is defined and is used for determining the presence or absence of tint. If the number of contours is below the specified threshold limit, then the tested windshield/window tinting is not allowed according to the norms, and the process will switch to the next module, namely number plate detection.

The third technique is called "Histogram analysis" and is used for visually judging whether the image is in an appropriate range of gray level. Ideally, digital image should use all available gray-scale range, from minimum to maximum. From histogram of tint image (final extracted image), we can judge the presence of tinting on windshield/window. If the histogram of the extracted image has only two peaks of gray level, then it has undesired tinting level. If the histogram of the extracted image shows multiple peaks in the histogram, then we can conclude that there is desirable level of tinting. These three methods collectively can determine the tinting level of window/windshield region. Figure 1.8 shows the flow chart of various tint level detection algorithms used in our present work.

After identifying the tinting level of vehicle window/windshield using these three techniques, the process is switched to number plate identification module. If tinting level is more than the desired level (prescribed norms by state/country), then it switches to number plate identification module; otherwise, the test ends for the current vehicle. After identifying the license plate registration number of a given vehicle, the system

TABLE 1.1

Various Tinting Level on Green/Blue Channels and Corresponding RGB% Level Present in the Image

	Green(grass) Value			Blue(sky) Value		
Tint VTL%	**R%**	**G%**	**B%**	**R%**	**G%**	**B%**
No tint	49	55	20	67	75	68
50%	30	34	12	57	60	67
35%	16	22	8	40	40	40
30%	14	14	6	25	25	29
20%	9	9	3	19	19	21
15%	6	6	2	12	12	13
5%	0.4	0.4	0.4	0.4	0.4	0.4

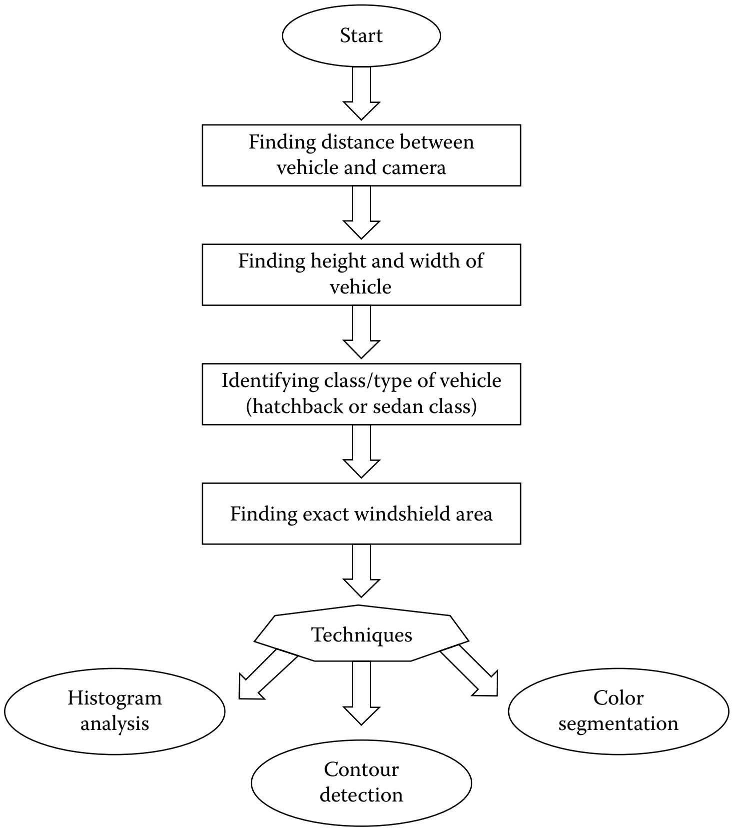

FIGURE 1.8
Various window tint level detection techniques used in the proposed system.

captures the image of the vehicle for the purpose of proof and saves it in a controller (or server). The controller is interfaced with a GPS device which provides the location details of the place where the images were captured and appends the system date and time. All these parameters are sent to the server system which stores all the received data. The vehicle registration number is extracted from the captured image and is searched in the available database, and the vehicle owner's contact details are traced for sending evidence to issue a ticket.

1.4.5 License Plate Detection

This is an important stage in vehicle license plate detection in the location of the license plate. The license plate area contains a good amount of edge and texture information. The license plate of the vehicle consists of several characters, and hence contains rich edge information. At times, the background of the vehicle image also contains much edge information. The interesting fact is that the background areas around the license plate mainly include some horizontal edges whereas the edges in the background mainly contain long curves and random noises. Also, the edges in the plate area cluster together and produce intense texture feature. If only the vertical edges are extracted from the vehicle image and most of the background edges are removed, then the plate

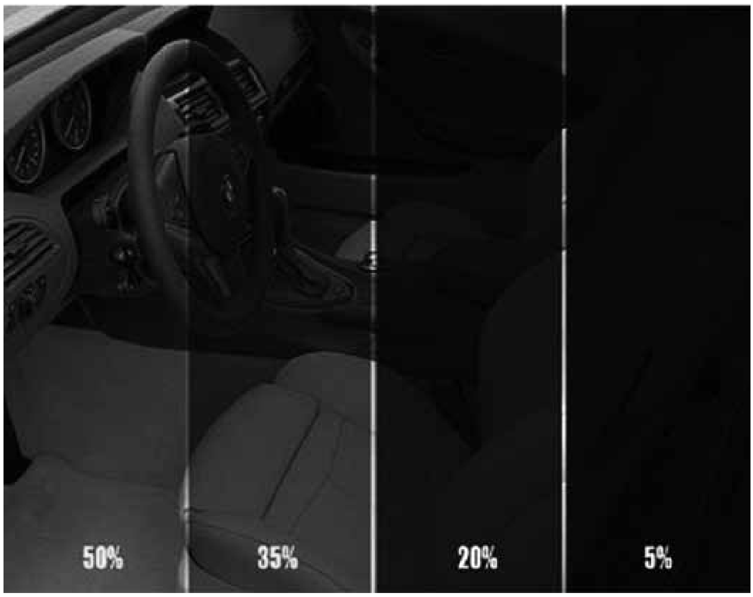

FIGURE 1.9
Effect on vision due to various tinting levels applied on windows.

area will be isolated out distinctly. The algorithm proposed in the present work contains four parts: image enhancement, vertical edge extraction, background curve and noise removal.

Figure 1.9 shows the effect on vision due to various tinting levels applied on windows and the corresponding darkness value. From Figure 1.9, we could clearly see that when the VTL value is less than 35%, it is very difficult to see the objects/persons present inside the vehicle. Due to this reason, many law enforcement authorities in various states/countries insist that the threshold value of VTL should be 35% or more.

Figure 1.10 shows the design of controller module for further processing. The vehicle under surveillance is tested for windshield/window tinting level. If the tinting level is up to the desired level, then the testing is continued for the next vehicle; otherwise, for the same vehicle, we switch to number plate identification module. After identifying the "vehicle number" of the vehicle, the GPS data or location ID, time, and date along with the proof of tinting level (processed image) are sent from the client system (surveillance camera system) to the server. The server checks the vehicle registration number in its database and locates the owner's contact details and accordingly issues a ticket to the owner of the vehicle.

1.5 Results and Conclusions

Figure 1.11 shows the various input images which are preprocessed and subtracted from background image. Then, the output is given to find the object(s) present in the image. Finding its extreme points gives us extracted or segmented image from which our main object of interest, namely the window is extracted. For the first set of input images, the RGB percentages are 45%, 43.16%, and 44%, respectively, which are greater

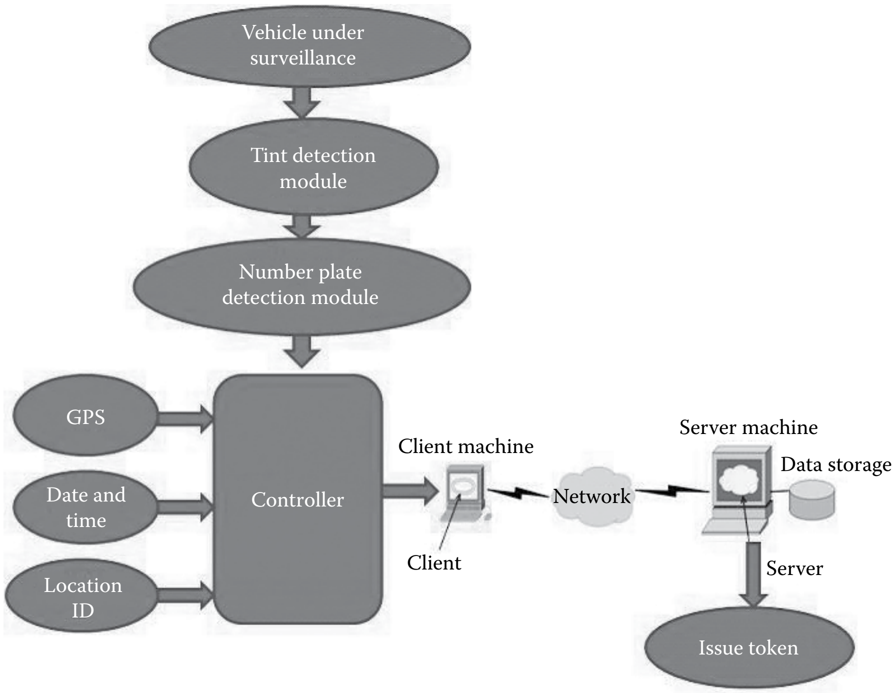

FIGURE 1.10
The controller modules for issuing ticket with evidence.

than 35% VTL color percentages. For the second set of input images, the RGB percentages are 14%, 16%, and 16%, respectively, which are less than 35% of VTL, and hence one can conclude that the dark tinting is present in the windows of those vehicles. The various input images given clearly identify and classify the vehicles based on tinting levels.

In conclusion, in the present work, we extract the relevant, meaningful images from the captured video frames. From the captured images, through motion detection techniques, the presence or absence of a vehicle is determined. If a vehicle is present, it is classified using appropriate imaging techniques. Depending on the type of vehicle, the ROI is identified and vehicle image alone is cropped for further processing. Depending on the vehicle type, the windshield/window region is identified and that portion of the image is used for further processing. Using three different techniques, namely color segmentation, contour detection, and histogram analysis, the tint level of windshield/window region is estimated. The tint level on the detected vehicle is verified against the database of government permissible limits. If the tint level exceeds government norms, the imaging system extracts the license plate of the vehicle. If the level exceeds the limits of regulation bodies, the controller/processor interfaced with the surveillance system extracts the GPS details from the GPS receiver and appends it with date and time. A messaging system (such as SMS/MMS/e-mail) interfaced with the surveillance system automatically generates an evidence consisting of latitude, longitude, date, time, license/plate image, vehicle with tinted window/windshield image for issuing necessary tickets. The messaging system stores the evidence at the central server. At the server side, using the number

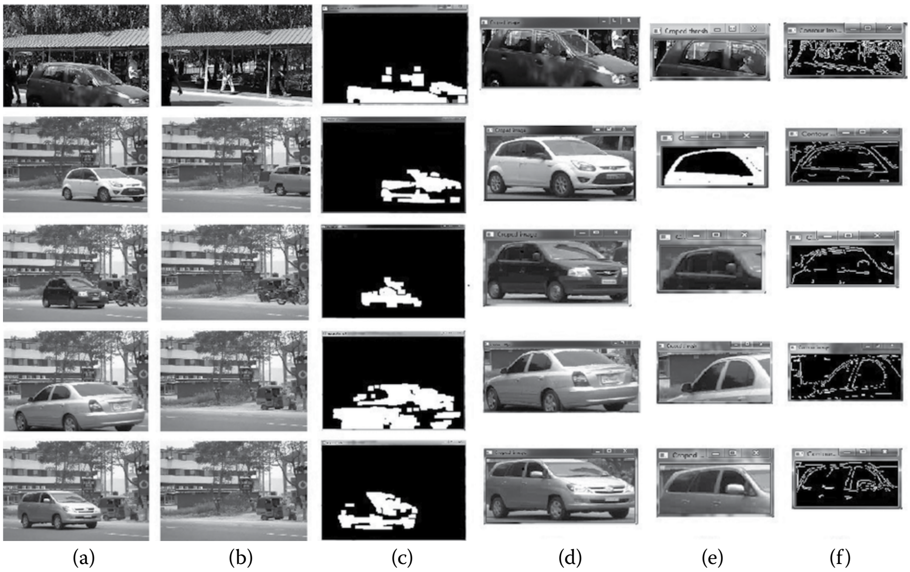

FIGURE 1.11
Experimental results. (a) Input foreground image, (b) input background image, (c) result of background subtraction where car (object) location is represented as white pixel, (d) detected portion from foreground image, (e) from cropped car, window position is identified, and (f) drawn contour on windshield portion and the available contour in image is identified.

plate information, the contact details of the owner is identified and ticket is issued with necessary proof or evidence.

1.6 Scope for Future Studies

The proposed tint level detection system has been designed using ordinary cameras which work in the visible region of the electromagnetic spectrum. In reality, we drive our vehicles during early mornings, late evenings, and night times as well. If one wants to use the proposed system, then one has to use infrared cameras during those poor lighting conditions. Then, the proposed algorithm needs to be modified. The designed algorithm has been tested while the vehicles were moving at low speeds. One has to test the algorithm while vehicles are moving at high speeds.

Acknowledgments

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