DESIGN AND DEVELOPMENT OF ANIMAL DETECTION ALGORITHM USING IMAGE PROCESSING

A Thesis submitted to Gujarat Technological University

for the Award of

Doctor of Philosophy

in

Electronics and Communication Engineering

By

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Enrollment No. 119997111011

under supervision of

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GUJARAT TECHNOLOGICAL UNIVERSITY

AHMEDABAD

May – 2017

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ABSTRACT

One serious problem that all the developed nations are facing today is death and injuries due to road accidents. The collision of an animal with the vehicle on the highway is one such big issue apart from other issues such as vehicle over-speed, abrupt lane change, drunk-drive and others, which leads to such road accidents. In this thesis, a simple and a low-cost system for automatic animal detection on highways for preventing animal-vehicle collision using image processing and computer vision techniques is presented. A method for finding the distance of the animal in real-world units from the camera mounted vehicle is also presented. The presented system is trained on more than 2200 images consisting of positive and negatives images and tested on various video clips of animals on highways with varying vehicle speed. As per the two-second rule, our developed system is able to alert the driver when the vehicle speed is up to 35 kmph. Though the developed system has been focused on automatic animal detection in context to Indian highways but it will work in other countries also. The developed system can easily be implemented in any cars and can be extended to detect other animals also after proper training and testing to prevent collision of animals with vehicles on the road.

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At the end, I would like to thank and acknowledge my family members who were always with me and for me during this whole journey. I would like to dedicate this to my father, **Shri. Umesh Chandra Sharma,** who himself was a teacher and his last wish were to see me finish this research work. He was always there for me whenever I needed his help. My mother, **Smt. Urmila Sharma**, who always encouraged me and while worshiping God, was asking for my PhD completion only and nothing for herself.

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Table of Content

List of Abbreviations

ADS: Animal Detection System

AdaBoost: Adaptive Boosting

CVAAS: Camel-Vehicle Accident Avoidance System

CBIR: Content-Based Image Retrieval

CUDA: Compute Unified Device Architecture

FPR: False Positive Rate

FNR: False Negative Rate

FP: False Positive

FN: False Negative

GAB: Gentle Adaptive Boosting

GPS: Global Positioning System

GPRS: General Packet Radio Service

HOG: Histogram of Oriented Gradients

IVS: Intelligent Vehicle System

LBP: Local Binary Pattern

LIDAR: Light Detection and Ranging

NCRB: National Crime Records Bureau

OpenCV: Open Source Computer Vision

ROC: Receiver Operating Characteristic

ROI: Region of Interest

SVM: Support Vector Machine

SIFT: Scale-Invariant Feature Transform

SPCA: Society for Prevention of Cruelty to Animals

TPR: True Positive Rate

TNR: True Negative Rate

TP: True Positive

TN: True Negative

XML: Extensible Markup Language

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CHAPTER – 1

Introduction

1.1 Background and Motivation

Today's automobile design primarily depends on safety measures, security tools and comfort mechanism. The approach has facilitated the development of several intelligent vehicles that rely on modern tools and technology for their performance. The safety of an automobile is the highest priority according to a recent report [1]. The report commissioned by World Health Organization in its Global Status Study on Road Safety 2013, revealed that the primary cause of death for young people (15-29 age) globally is due to road traffic collisions. Even though various countries have initiated and taken steps to reduce road traffic collisions and accidents, the total number of crashes and traffic accidents remain as high as 1.24 million per year [2]. Road traffic accidents and injuries are expected to rise by almost 65% by the end of 2020 [3]. Due to road accidents, every year 1 out of 20,000 persons lose their life and 12 out of 70,000 individuals face serious injuries in India [4]. India is also known for the maximum number of road accidents in the world [5]. According to the data given by National Crime Records Bureau (NCRB), India, there were almost 118,239 people, who lost their life due to road accidents in the year 2008 [6]. A major percentage of these road crashes and accidents involved car and other vehicles.

Road accidents are increasing due to the increase in the number of vehicles day by day and also the due to the absence of any intelligent highway safety and alert system. According to data given in a study [7], the number of people, who lost their lives in India due to road accidents was almost 0.11 million deaths in 2006, which was approximately 10% of the total road accident deaths in the world.

According to the accident research study conducted by JP Research India Pvt Ltd. for the Ahmedabad-Gandhinagar region (cities of India), for the duration February 2014 to

January 2015, total 206 road traffic accidents were recorded and these were influenced by three main factors i.e. human, vehicle, infrastructure or a combination of them [8].

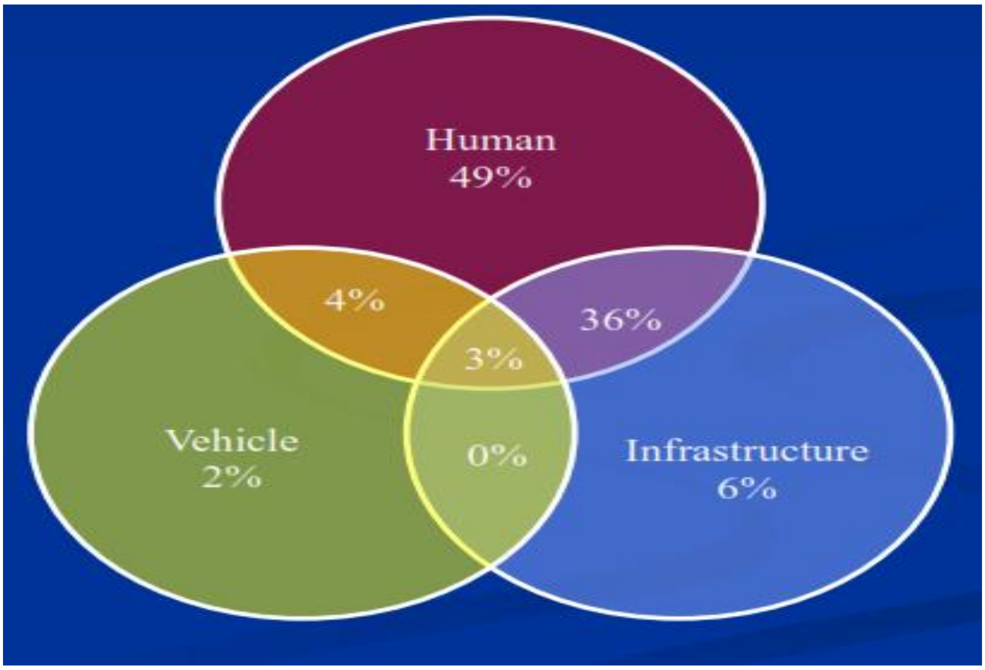

FIGURE 1.1: Influences on road traffic accidents [8]

The number in figure 1.1 is a percentage of the total number of accidents surveyed. According to the record, human factor influence on road traffic accidents was 92%, vehicle 9% and infrastructure 45%. Out of total 45% (91 accidents) infrastructure influenced road accidents, 6% (12 accidents) were due to animals on the road whereas out of total 92% (171) human factor influenced road accidents, 14% (24) were due to driver inattention and absence of any timely alert system for preventing the collision. Similar types of surveys were conducted for the Mumbai-Pune expressway, and Coimbatore by JP Research India Pvt Ltd. and the conclusions hinted at a significant percentage of road accidents resulting due to an object (animals) on the road, driver inattention, and absence of any intelligent highway safetyalert system.

1.2 Evidences of Animal-Vehicle Collision

According to the report given by the Society for Prevention of Cruelty to Animals (SPCA), around 270 cattle had been brought to their hospital-cum-animal-shelter in the year 2013, most of whom were accident victims [9]. In one of the article (report) published by a leading newspaper (Indian Express) on 26th August 2012, it is mentioned and notified that stray animal menace turns deadly on city roads and animals on the road create many difficulties for the drivers in Odisha state [10]. In another article published by ArriveSafe on 15th May 2008 (an organization working on road safety motive), it is mentioned that though no information is available on the cost of road accidents but the number of deaths due to road accidents are increasing, and one of the leading causes of road accidents is stray animals apart from over-speeding [11]. Apart from other issues, animal threats on the road, Chandigarh Police advises drivers to wear seat belt, drive slowly and take every safety related precautions to prevent possible collision of drivers with obstacles on the road (including vehicles, animals, and pedestrians) [12]. Below are some of the snapshots of the same with the sources (figure 1.2), which suggests that there are many challenges that the drivers are facing because of animals on the road.

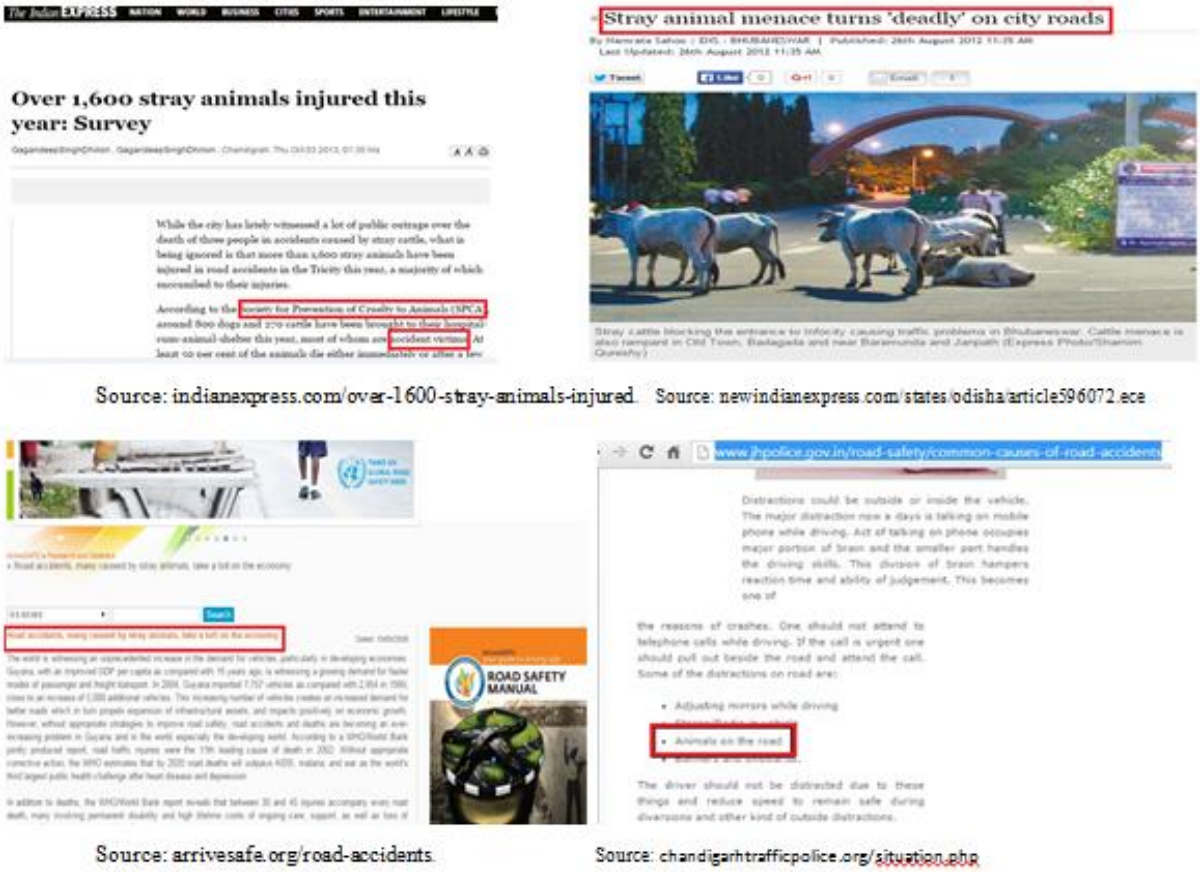

FIGURE1.2: Snapshots indicating the effect of animal-vehicle collisions [9-12]

1.3 Animal Detection: Challenges and Issues

Comparing with vehicle number plate, human-face, or traffic sign detection/identification, a lot of problems and difficulties have to be addressed in animal detection. With animal detection (example cow, dog, cat, deer and other animals), too many differences in colour, shapes, and other variations are observed [13]. Following are the challenges and issues faced during animal detection on highways:

1.3.1 Different Body Postures

The body postures of the roadside animals show very high variability within the same class, and between the various classes. Compared to human face and body, which are almost standard and unique, the animal body have more variations in appearance. The human body's outlines are nearly invariable even, when they are walking in different directions. It is almost impossible to detect all animal shape categories from one detector based on current image processing technology.

1.3.2 Blurring of Image

The camera (on-board camera) mounted in a testing vehicle to detect/identify a moving, or stationary animal will cause the blurred image due to many reasons such as vibration, when the car is moving fast or running on a bumpy road or while making a turn, the camera gets out of focus. All these situations (circumstances) will affect and probably reduce the detection rate and cannot be avoided altogether.

1.3.3 Lighting/Illumination Conditions

The image colour is very sensitive to the variation of the light intensity and lighting directions. The light of the outdoor environment varies and uncontrollable since it changes along with the vehicle's lighting, different time of a day, different seasons, and different weather conditions. Besides that the light from the sun or other light sources will get reflected by the surface of the road or other objects, and the light will naturally affect the video quality, which may cause problems in catching our target.

1.3.4 Mobility of Animals and Testing Vehicle

Animal detection in wildlife (forest) videos or underwater videos (controlled areas) have been tried in past but the challenges are much more when detecting animals on highways (uncontrolled areas) as both animal as well as a camera mounted vehicle is moving, apart from that other obstacles on the road, which are also moving or stationary. This situation complicates the animal detection. There is no issue of speed (vehicle speed as well as animal speed) and detecting distance of animal from the vehicle in wildlife videos, which is crucial and critical in animal detection on highways. So dynamism of the object and environment need to take into account for detection of animals on the highway.

1.3.5 Animal Detection Accuracy

Accuracy means how accurately the system can detect/identify animals on the roads. It can be improved by reducing the false positive rate and false negative rate. False positive happens when the system generates an alert signal (false warning) without any animal present in the scene, which can distract and disturb drivers in their driving task. On the other hand, false negative happens when the system is not able to detect or identify animals moving or crossing the roads even when the animal is present in the scene. If false negative occurs in sequential frames, it could be very dangerous for both drivers and animals.

1.4 Different Scenarios and Consequences of Animal-Vehicle Collision

Animal-vehicle collision can be classified using two ways [14]:

1) Direct collision
2) Indirect collision

Direct collision: It happens when the vehicle directly hits the animal. Following cases and outcome may occur depending on the speed of the vehicle and the speed of the incoming or outgoing animal.

Case 1: Vehicle hits the animal and animal gets thrown to the side. This scenario may be less critical, but damages will be there. Figure 1.3 shows the case 1 scenario.

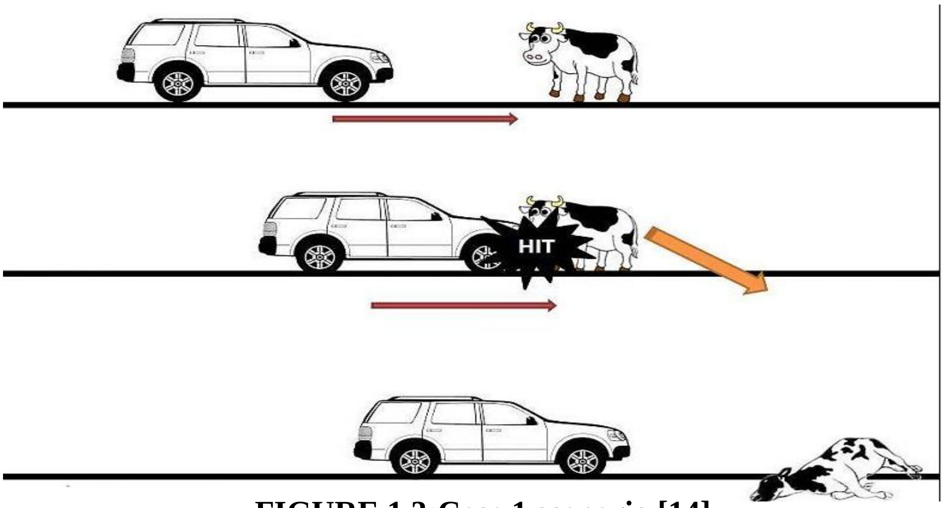

FIGURE 1.3:Case 1 scenario [14]

Case 2: Vehicle hits the animal, and the animal jumps/ gets raised in the air and again gets back or falls back on the windshield. This is quite critical and dangerous scenario and can cause the death of the animal or even the driver of the vehicle. Figure 1.4 shows the case 2 scenario.

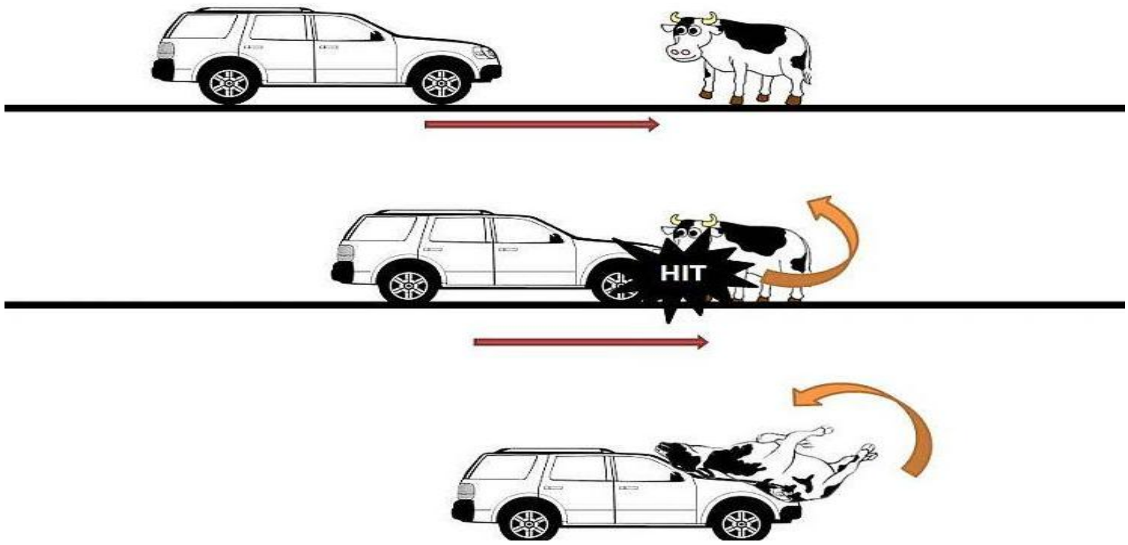

FIGURE 1.4:Case 2 scenario [14]

Case 3: Vehicle hits the animal and runs over the animal. In this case, a definite injury will occur to the animal. It may also happen that because of the impact of a collision, the vehicle may get overturn which can cause injury to the driver. Figure 1.5 shows the case 3 scenario.

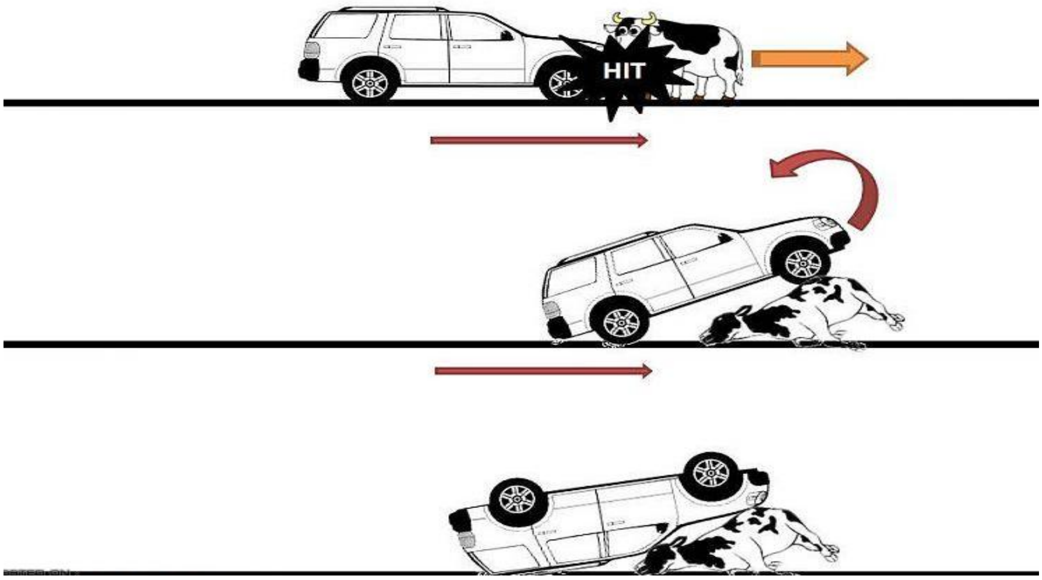

FIGURE 1.5:Case 3 scenario [14]

Indirect collision: In this case, an accident occurs because of animal only but not directly. The driver of one vehicle finds an animal on the highway and tries to change the direction or the lane and collides with the vehicle, which is running on the other lane. Figure 1.6 shows the indirect collision scenario.

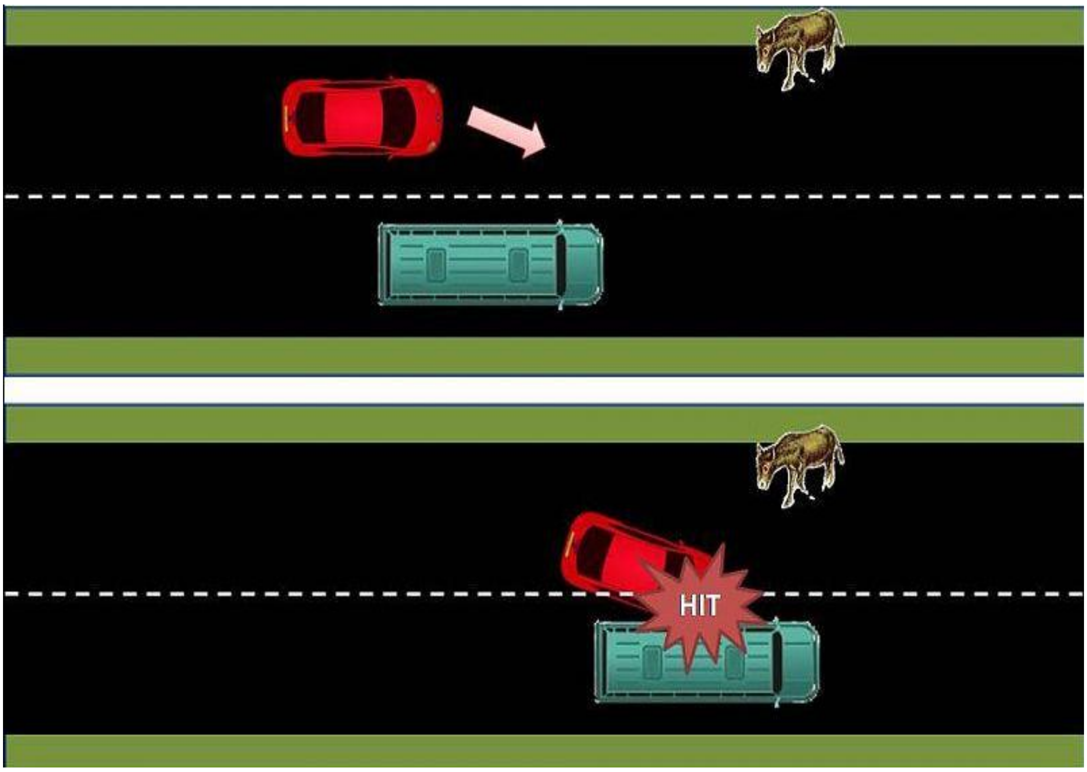

FIGURE 1.6:Indirect collision scenario [14]

In all the cases as discussed above, if the driver has some automatic animal detection system in the vehicle, then it is possible to some extent to prevent injuries and collisions between vehicle and animal.

1.5 Objectives and Scope of Work

Intelligent highway safety and driver assistance systems are very helpful to reduce the number of accidents that are happening due to animal-vehicle collisions. On Indian roads, two types of animals – the cow and the dog are found more often than any other animals on the road. The primary focus of the proposed work is to detect animals on roads, which can have the potential application of preventing an animal-vehicle collision on highways. Specific objectives of the research work are:

1. To develop a low-cost automatic animal detection system for roads and highways.
2. To find the approximate distance of the detected animal from the camera mounted on vehicle.
3. To develop an alert system once the animal gets detected on the road, which may help the driver in applying brakes or taking other necessary corrective action for avoiding collision between the vehicle and the animal.

1.6 Specific Reasons for Cow Detection

According to the surveys and report given by the Society for Prevention of Cruelty to Animals (SPCA) and other leading newspapers [9 -12], the number of accidents on Indian roads has increased due to increase in a number of vehicles day by day and also due to the presence of animals on the road (mainly two animal's dog and cow). The collision of an animal with the vehicle on the highway is one such big issue apart from other problems such as over speed, abrupt lane change, drunk-drive and others which lead to such road accidents and injuries. The associated number of fatalities and injuries are substantial too.

Specific reasons behind developing automatic cow detection system in place of any other animal are:

1. India is mainly an agriculture based country where 70% of people depend on agriculture, and 98% of them depend on cow based agriculture.
2. The cow is a sacred animal in India and nobody wants to hit a cow.
3. Cow milk is the most useful and compatible with human mother’s milk than any other animal or so.
4. According to some surveys, cow’s milk and cow dung have many medicinal benefits.
5. Cows, as well as dogs, are found quite often than other animals on the Indian roads.
6. As cow is a large (heavy) sized animal, the collision between a cow and vehicle will be very much severe. The collision between a small (less weight) sized animal like dog and car won't be that much severe. The speed with which the vehicle is coming and hitting the animal also plays a critical role in deciding the impact of the collision.

1.7 Organization of Remainder of Thesis

This thesis is organized as follows.

In chapter 2, the literature survey and related works in animal detection field is mentioned.

In Chapter 3, an overview of two popular image feature descriptors i.e. Haar-like features and HOG (Histogram of Oriented Gradients) features, which are widely used in objects detection field, are presented. These descriptors are used for feature extraction in the image.

After that, in Chapter 4, a very popular and widely used classification algorithm i.e. boosting cascade classifier is discussed. Boosting cascade classifier helps to separate the actual targets (object of interest) from the negative samples.

How to create an animal database, which can be used for training and test the classifier/animal detection system is discussed in Chapter 5. As our research is focussed on automatic animal (cow) detection in context to Indian roads and conditions, we have created a new animal database as no general benchmark database of animals exists in the literature as per our survey and knowledge. This animal database will be regularly updated by adding more new animal images.

Chapter 6 is the central and the crucial part of the thesis. In this chapter, we have presented our proposed research methodology for building an automatic animal detection and collision avoidance system. Procedures for classifier training and testing with all the necessary parameters required during training are discussed. A method for finding the distance of the detected animal in real-world units from the camera mounted vehicle is also presented. Subsequently, we present the experimental setup, implementation and testing of the proposed animal detection system.

Chapter 7 parameters, which are necessary for checking the performance (detection accuracy) of the classifier/system, are discussed along with the results. A thorough discussion of the results of the implemented animal detection and collision avoidance system with different vehicle speed and different weather conditions (morning, afternoon and evening) is presented. Comparison of results of our proposed method based on the combination of HOG and cascade classifier with the combination of Haar and cascade classifier is presented separately.

Finally, Chapter 8 includes the conclusion, objectives achieved, the limitation of the proposed system and the possible future work.

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CHAPTER – 2

Literature Review

2.1 Introduction

A literature survey of the related existing work is necessary during the entire course of doctoral work. This chapter is the outcome of the initial literature review which helped us to find the research gap and issues faced while detecting animals on the road.

2.2 Related Work and Discussion

Applications built on detection of animals play a very vital role in providing solutions to various real-life problems [1]. The base for most of the applications is the detection of animals in the video or image.

A recent study [2] shown that human beings have to take the final call while driving whether they can control their car to prevent collision with a response time of 150ms or not. The issue with the above approach is that human eyes get exhausted quickly and need rest, which is why this method is not that effective. Some scientific researchers [3] have proposed a method that requires the animals to take a pose towards the camera for the trigger, including face detection. The problem with this technique is that face detection requires animals to see into the camera which is, not necessarily captured by the road travel video. Animals can arrive from a scene from various directions and in different sizes, poses, and color.

Animals can be detected using the knowledge of their motion. The fundamental assumption here [4] is that the default location is static and can simply be subtracted. All blobs, which stay after the operation are measured as the region of interest. Although this technique performs well in controlled areas, e.g. underwater videos, it does not work universally, especially road or highway side videos. Researchers [5] used threshold segmentation approach for getting the targeted animal's details from the background. Recent researches [6] also revealed that it's hard to decide the threshold value as the background changes often. A method applicable to moving backgrounds (e.g., due to camera motion) is presented in subsequent studies [7] and [8]. The authors also state that other moving objects apart from the object of interest may be falsely detected as an animal.

Researchers in [9] tried to discover an animal's presence in the scene (image) affecting the power spectrum of the image. This method of animal detection was also considered not appropriate since quicker results with this approach would involve the massive amount of image processing in a short period [10].

Researchers in [11] also used the face detection technique initiated by Viola and Jones for a particular animal type. After the animal face is identified, the researchers track it over time. The problem with this technique is that face detection requires animals to see into the camera not necessarily captured by the road travel video. Animals can arrive from a scene from various directions and in different sizes, poses, and colors.

Another method for animal detection and tracking that uses texture descriptor based on SIFT and matching it against a predefined library of animal textures is proposed in [12]. The problem with this method is that it is restricted to videos having single animal only and very minimal background clutter.

In Saudi Arabia, the number of collisions between the camel and a vehicle was estimated to reach more than a hundred each year [13]. Authors in [13] implemented a deployable Camel-Vehicle Accident Avoidance System (CVAAS) and exploited two technologies GPS and GPRS to detect the camel position and then transmit that position to the CVAAS server consequently. The CVAAS server checks the camel position and decides to warn the drivers through activating the warning system if the camel is in the danger zone. Authors in [13] do mention that cost of deploying such CVAAS on a great scale is too much. Also, the system suffers from many false negatives due to dependency on many parameters like a width of the dangerous zone, variation in camel speed and delay in receiving SMS message.

Authors in [14] designed a system, which uses web cameras which are to be placed in the detecting areas from where the animal may cross their boundary. The videos are sent to the processing unit and then uses image mining algorithm, which identifies the change in set reference background. If there is a change in the newly acquired image, then authors applied content-based retrieval algorithm (CBIR) to identify the animal. The proposed method in [14] based on CBIR algorithm suffers from many issues like unsatisfactory querying performance-CBIR systems uses distance functions to calculate the dissimilarity between a search image and database images resulting in low-quality recovery results. This approach is very slow and response times in the range of minutes may take place if size of database is too large. To find the accurate location of fishes in the marine, researchers [15] aimed a technique using LIDAR (light detection and ranging). Some of the above-specified methods have been discussed in [16] [17] also.

2.3 Research Gap and Challenges

Though various practical solutions for automatic lane detection and pedestrian detection on highways are available still research related to automatic animal detection on highways is going on. Following are the challenges and issues faced during animal detection on highways:

1. Animal detection in wildlife (forest) videos or underwater videos (controlled areas) have been tried in past but the challenges are much more when detecting animals on highways (uncontrolled areas) as both animal as well as a camera mounted vehicle is moving apart from other obstacles on the road, which are also moving or stationary. There is no issue of speed (vehicle speed as well as animal speed) and detecting distance of animal from the vehicle in wildlife videos but it is crucial and critical in animal detection on highways.

2. The biggest challenge in detecting animals compared to pedestrians or other objects is that animals are in various size, shape, pose, color and their behavior is also not entirely predictable. Though the basic shape and size of a human being are pretty average and standard, the same is not true for animals.

3. Although various methods and approaches have been used and are still in progress to detect, solve and reduce the number of animal-vehicle collisions, the absence of any practical systems related to an animal-vehicle collision on highways has delayed any substantial development in the scenario [16].

References:

[1] Sharma S and Shah D, 2013, A brief overview on different animal detection method, Signal and Image Processing: An International Journal, vol. 4, pp: 77-81.

[2] Thorpe M, Delorme A and Marlot T, 2001, A limit to the speed processing in ultra-rapid visual categorization of novel natural scene, Journal of Cognitive Neuroscience, vol. 13, pp:171-180.

[3] Burghardt T, Calic J (2006) “Analyzing animal behaviour in wildlife videos using face detection and tracking”, *IEE Proceedings - Vision, Image and Signal Processing (IET Journals and Magazines)*, pp. 305-312.

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CHAPTER – 3

Image Features Extraction

3.1 Introduction

Image features extraction is the method of defining a set of features, or image characteristics, which will most efficiently or meaningfully represent the information that is necessary for detection analysis and classification [1]. The primary purpose of features extraction is to improve the effectiveness and efficiency of object detection and classification.

There are many feature extraction methods such as using HAAR Transforms, LBP (Local Binary Pattern), HOG (Histogram of Oriented Gradients) and other methods that focus on detection of an object. The remaining content of this chapter will discuss a popular and widely used feature descriptor HOG. HOG descriptor is mainly suitable for pedestrian or animal detection in video or images due to some key advantages as explained in the remaining part of this chapter compared to other descriptors.

3.2 Histogram of Oriented Gradients (HOG) Features

A histogram of oriented gradients (HOG) is used in image processing applications for detecting objects in a video or image, which by definition is a feature descriptor [2], proposed by Dalal and Triggs who used their method for pedestrian detection. Figure 3.1 and 3.2 shows the block diagram and block normalization scheme of HOG feature extraction.

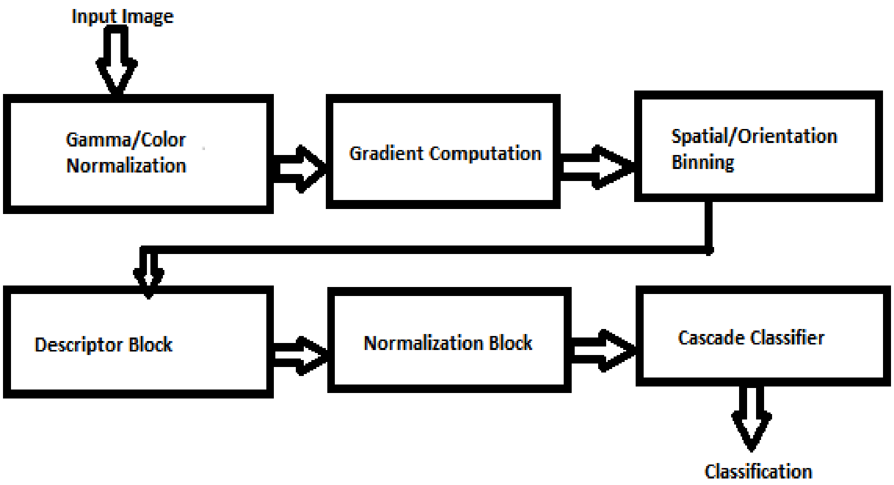


FIGURE 3.1: HOG algorithm [2]

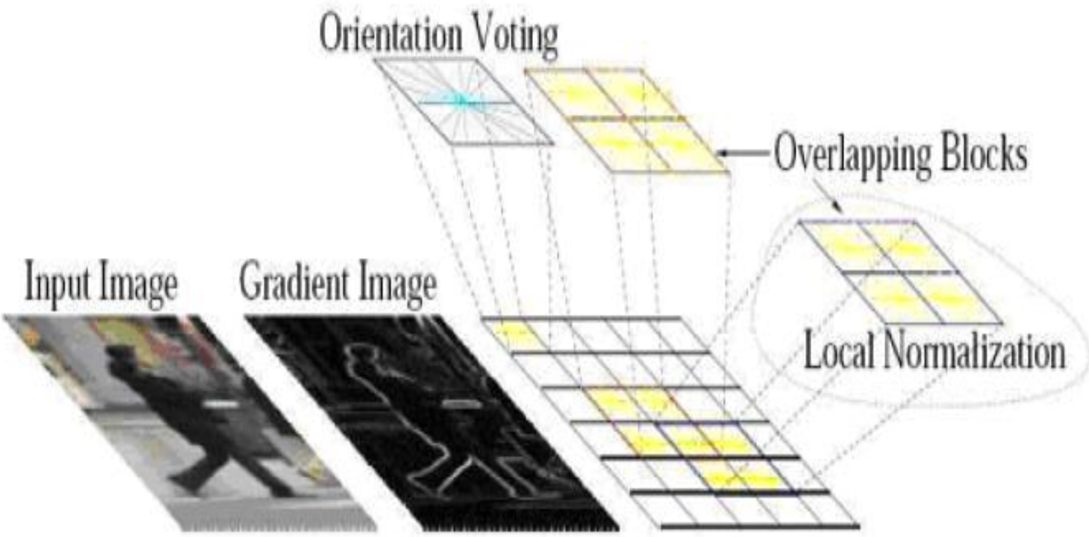


FIGURE 3.2: Block normalization scheme of HOG [2]

3.2.1 Gradient Computation

As shown in figure 3.1, the input image is given to gamma and color normalization block. Color normalization is used for object recognition on color images where it is important to remove all intensity values from the image while preserving color values. After color normalization, the next step involves computing the gradient values by applying 1D centered point discrete derivative mask in both vertical and horizontal directions. Specifically, this approach involves filtering the gray scale imagewith the following filter kernels:

$$D_X = \begin{bmatrix} -1 & 0 & 1 \end{bmatrix} \quad \text{and} \quad D_Y = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix} \tag{3.1}$$

So, given an image *I*, we obtain the x and y derivatives using a convolution operation:

$$I_X = I \times D_X \quad \text{and} \quad I_Y = I \times D_Y \tag{3.2}$$

Then the magnitude of the gradient is given by:

$$|G| = (I_X^2 + I_Y^2)^{0.5} \tag{3.3}$$

and orientation of the gradient is given by:

$$\theta = tan^{-1} \ (I_Y / I_X) \qquad (3.4).$$

3.2.2 Cell Histogram and Feature Vector Generation

After gradient computation, the next step is to create the histogram of the cells. Within the cell, each pixel casts a weighted vote for an orientation-based histogram channel based on the values found in the computation of the gradients. The cells are rectangular, and the histogram channels are uniformly spread over 0 to 360 or 0 to 180 degrees, depending on whether the gradient is "signed" or "unsigned". As for the vote weight, pixel contribution can be the gradient magnitude itself, or the square root or square of the gradient magnitude.

The gradient strengths need to be normalized locally in order to account for changes in contrast and illumination, which basically involves combining/grouping the cells together into larger, spatially-connected blocks, which is the next step. The HOG descriptor is then the vector of the components of the normalized cell histograms from all the block regions. These blocks overlap and each cell contributes more than once to the final descriptor (see figure 3.2).

Normally two block geometries are present and used i.e. rectangular R-HOG blocks and circular C-HOG blocks. R-HOG blocks are square grids and represented by three parameters: the number of cells per block, the number of pixels per cell, and the number of channels per cell histogram. Different methods for block normalization are also there. Let *v* be the non-normalized vector comprising all the channel histograms in a given block, $\|v\|_k$ be its k-norm for $k = 1, 2$ and *e* be some constant (value of *e* is small as experimented and discussed by Dalal and Triggs in [2] and does not affect the results). One of the following normalization factors can be used:

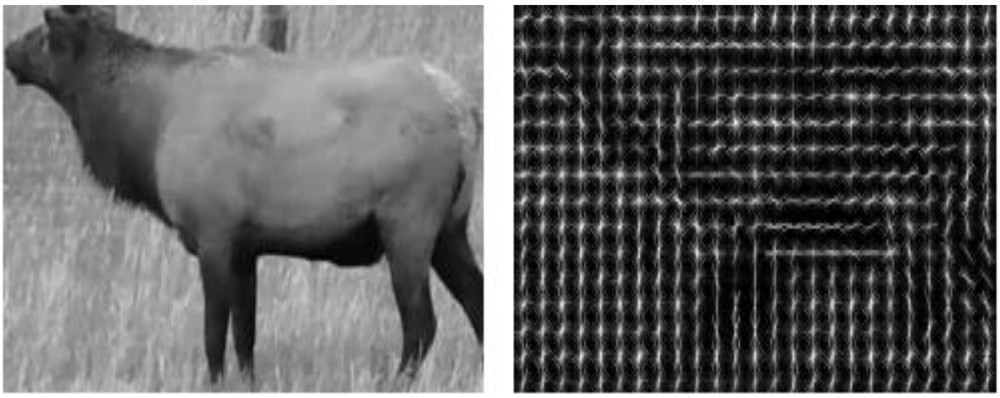
$$L1-norm\colon V = v/(\ \|v\|_1 + \ e\ ) \tag{3.5}$$

$$L1-sqrt\colon V = \left(\frac{v}{\|v\|_1 + \ e}\right)^{0.5} \tag{3.6}$$

$$L2-norm\colon V = \left(\frac{v}{\|v\|^2_2 + \ e^2}\right)^{0.5} \tag{3.7}$$

$$L2-hys\colon V = \left(\frac{v}{\|v\|^2_2 + \ e^2}\right)^{0.5}, \qquad v \leq 0.2 \tag{3.8}$$

Note that the maximum value of *v* is limited to 0.2 as experimented and discussed in [2-3] to improve the performance. Finally, the image goes to cascade classifier for classification of the object. Figure 3.3 shows an initial (original) animal image and the image after applying HOG algorithm. Note that the outline indicates the presence of an animal in the HOG image.



(a) Original image **(b) After applying HOG algorithm**

FIGURE 3.3: Initial (original) image and image after applying HOG algorithm for an animal picture.

3.2.2 Cell Histogram and Feature Vector Generation

Note that in figure 3.3, each “∗" represents a cell with nine bins and the magnitude of this bin is shown or given by the luminance of each direction vector.

HOG descriptor is mainly suitable for animal detection in video or images due to some key advantages compared to other descriptors. Firstly it can describe contour and edge features exceptionally in various objects such as cars, bikes and animals such as cow, dogs, etc. Secondly, it operates on local cells, so it is invariant to geometric and photometric transformations which helps and allows different body movement of animals to be overlooked if they maintain a roughly upright position.

References:

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CHAPTER – 4

Data Classification

4.1 Introduction

The classification algorithm is the core of animal detection system. In brief, the role of classification is to determine whether the input sub-window contains an animal or not. Broadly speaking, given a set of training examples (image, human, data, etc.), each marked as belonging to one of M categories (generally, M = 2. animal or non-animal, face or non-face.), a classification algorithm builds a system or model that can assigns new examples which does not belong to the training examples into one category or others. The same process happens in image target detection. Classification algorithm in machine vision and image processing is that of determining whether or not the input image contains some particular object (human-face, pedestrian, animal, traffic sign, etc.). Once we have the features used to describe the image in detail, an algorithm is needed to justify whether it is target image or not. The algorithm has two main effects, the first is to process the image feature in training step to generate the classifier based on the image database and the second is to analyse the input image and detect the target. In this chapter, a popular boosting cascade classifier is presented.

4.2 Boosted Cascade Classifier

Boosting is a learning concept, which combines the performance of "weak" classifiers to create a powerful 'committee' [1]. A weak classifier is better than guess (chance) and is simple as well as computationally cheap. Combining them smartly can result in a robust strong classifier and it can outperform the strong classifiers such as Support Vector Machine (SVM) and Neural Networks.

Cascading classifier is a concatenation of various classifiers (group based learning). The technique involves taking all the data collected from the output of the first classifier as a supplementary data for the next classifier in the group [2]. The key advantages of boosted cascade classifiers over monolithic classifiers are that it is a fast learner and requires low computation time. Cascading also eliminates false positives candidates at an early stage, so later stages don't bother about them.

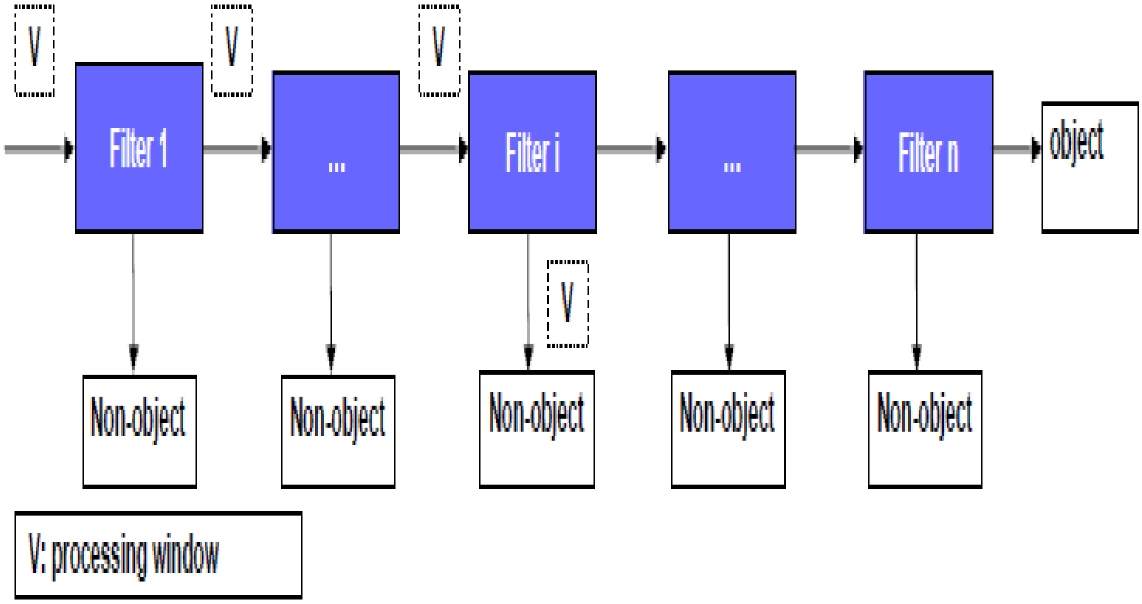

FIGURE 4.1: Boosted cascade classifier

As shown in figure 4.1, each filter (stage) rejects non-object windows and let the object windows pass to the next layer (stage) of the cascade. A window is considered as an object if and only of all layers (stages) of the cascade classifies it as object [2]. The filter *i* of the cascade is designed to:

1. Reject the possibly large number of non-object windows
2. To allow potentially large number of object windows for quick evaluation

Adaptive Boosting (AdaBoost), which is a machine learning meta-algorithm formulated by Yoav Freund and Robert Schapire, who won the Gödel Prize in 2003 and is adaptive in the sense that subsequent weak learners are tweaked for those instances misclassified by previous classifiers [3]. Adaptive Boosting (AdaBoost) training approach is applied to each stage and Histogram of Oriented Gradients (HOG) features as mentioned in the earlier chapter is considered as the input to each stages' classifier.

By re-weighting the training samples, boosting can learn and create a robust (strong) classifier based on a large set of weak classifiers. A weak classifier is better than guess (chance) and is simple as well as computationally cheap. Set of such weak classifiers are the classifiers, which uses one feature from the feature group in combination with a simple binary thresholding decision. At each stage of boosting, the feature-based classifier is added that best categorizes the weighted training samples. The number of weak classifiers which are required to attain the estimated false alarm rate at the given hit rate increases by increasing the number of stages.

The order of filters in the cascade is based on the importance weighting that AdaBoost assigns. The more heavily weighted filters come first, to eliminate non-object image regions as quickly as possible. The weights that AdaBoost assigns to each weak learner correspond to its importance and the choice of sum of weights as the rejection function is also based on AdaBoost's sum [4].

4.3 Selection of Parameters for Classifier Training

Assuming we need to train a cascade classifier with stage number N, then the false positive rate (FPR) and detection rate of the classifier are:

$$F = \prod_{i=1}^{N} f_i \ \ and \ \ T = \prod_{i=1}^{N} t_i \qquad (4.1)$$

where F and T in equation (4.1) are the FPR and the accuracy rate of the final classifier respectively. f_i and t_i are the FPR and the detection rate of the i^{th} stage classifier. If we want that the classifier achieves the detection rate of 90% (for the whole 20 stages), the minimum hit rate for each stage would be:

$$\log_{0.9} 20 \ \approx 0.995$$

At the same time, if we define the FPR of each stage classifier as ≤ 50%, the maximum false positive rate would be less than:

$$0.50^{20} \ \approx 0.95 \times 10^{-6}$$

which would be a very low false positive rate [4-5].

The number of positive samples (in which target animal i.e. cow is present) used in training database is a critical factor which dramatically affects the final detector's performance. Before we start building animal classifiers, we need to decide how many positive samples will be used in training process. Generally, the detection rate increases rapidly when the number of positive sample increases and then after some point, the detection rate remains stable.

Apart from the above mentioned parameters, other parameters like how many negative samples (in which target animal i.e. cow is absent) are to be used for training (usually negative samples should be more than the positive samples as there are many non-objects in the scene than the object of interest and classifier has to reject the non-object), which feature extraction method to use, what should be the width and height of training sample, how many cascade stages to be used, all these parameters are also needed to be mentioned and taken care of.

References:

[1] Freund Y, Schapire R (1996) “Experiments with a new boosting algorithm”,*Proceedings of the Thirteenth International Conference on Machine Learning*, San Francisco, pp. 148-156.

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CHAPTER – 5

Animal Database Collection

5.1 Creating Animal Database

As per our survey and knowledge, there is no public database of animals under consideration exists in the literature. As our research is focussed on automatic animal (cow) detection in context to Indian roads and conditions, we didn't get much data (images or videos) of cow needed to build a robust database. Even though a good source for the animal images is the KTH dataset [1] and NEC dataset [2] that included pictures of cow and other animals, some more animal videos and pictures have been clicked (during different weather conditions i.e. morning, afternoon and evening) and some of the images have been collected from the internet for creating a healthy database. Hence, a new animal database is created. It is very much essential to have good database and at the same time the quality of the database directly affects the final performance of the classifier.

The research work presented here mainly focuses on the cow, which is found more often than any other animals on Indian roads. The given system will not focus or deal with small size animals such as dog or cat as the collision of vehicle with small size (less weight) animals won’t be that much severe compared to collision of vehicle with large size (heavy weight) animals, which can be very severe and can lead to death or significant damage.

The biggestissue or the problem indetecting animals compared to pedestrians or other objects is that animals come in various size, shape, pose, color and their behavior is also entirely unpredictable. It is entirely unrealistic to build an omnipotent classifier, which can recognize all kind of animals with a casual pose.

5.2 Positive Sample Images Database

5.2 Positive Sample Images Database

In order to optimally utilize the characteristics of the classifiers we need to have positive as well as negative sample database. So immediately after creating database of images and videos next was to create two different folders in the database i.e. positive sample images database folder and negative sample images database folder. A positive sample image means it is an image having target animal (cow) present. In order to have better detection accuracy, the animal videos/images collected from moving vehicles are to be under different weather conditions (morning, afternoon and evening) and also should cover different postures of the animal (cow). A positive sample image database of more than 700 cow images with different views, shape (head to right and head to left) as well as the front, and rear view of the cow facing the camera mounted vehicle is created. Figure 5.1 shows some of the positive sample images of the cow.

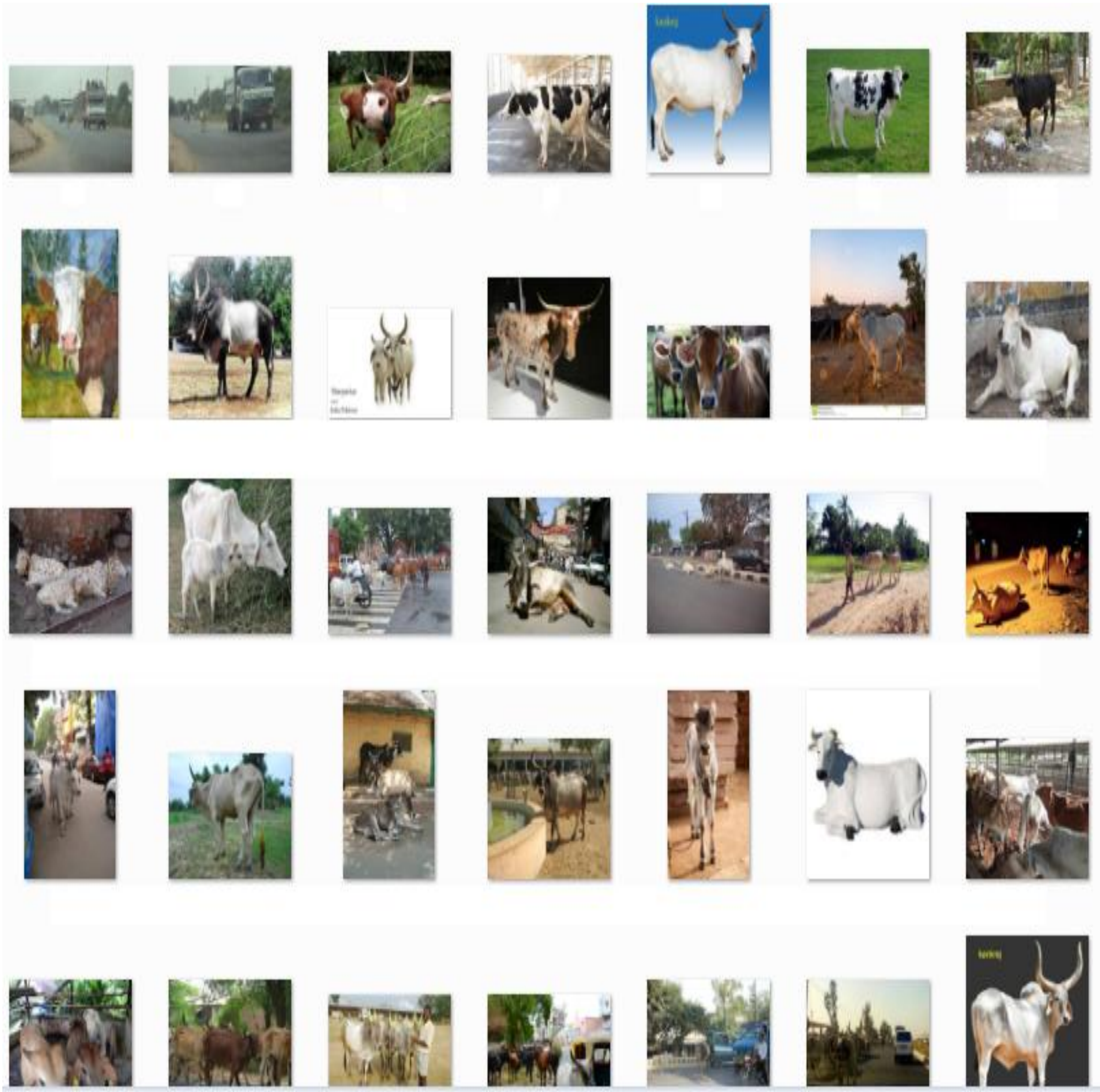

FIGURE 5.1: Positive sample images

5.3 Negative Sample Images Database

A negative sample image means it is an image where the target animal (cow) is absent. Detecting the object in the particular environment such as driving on the road, a real negative sample (background) database can certainly enhance final detector's performance. It is also important that in order to detect the animal (cow) in real time scenario, the background can be anything like road, vegetations, city areas etc. So negative sample image should contain them as well so as to make the target detection more effective and accurate.

Some of the important criteria's for creating a negative sample image database are:

1. The most important point is that the target animal (cow) should not be present in the database. Other animals like dog or cat, etc. should also be removed or excluded from the negative sample database, as they can also have similar structure (shapes) as large size animals (cow) have.

2. The database should contain road objects such as pedestrians, road surface, vehicles, traffic sign, etc. Different weather conditions and other environment conditions can be taken and considered.

A negative sample image database of more than 1500 background images is created for this research work. Figure5.2 shows some of the negative sample images.

5.3 Negative Sample Images Database

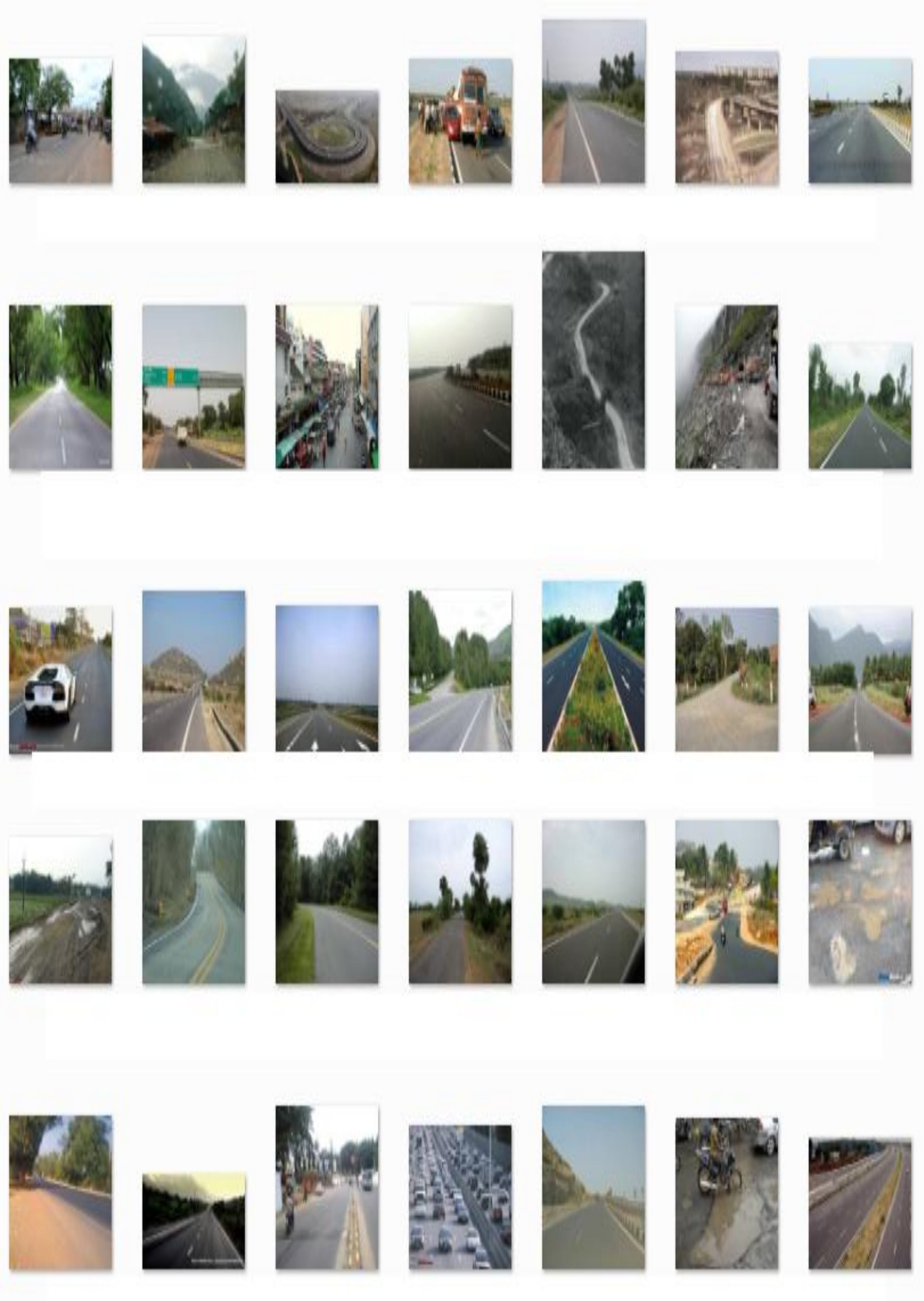

FIGURE 5.2: Negative sample images

References:

[1] KTH animal datasets. [Online]. Available: http://www.csc.kth.se/~heydarma/Datasets.html [Accessed 18 June 2013].

[2] NEC animal datasets. [Online]. Available: http://ml.nec-labs.com/download/data/videoembed [Accessed 18 June 2013].

CHAPTER – 6

Animal Detection System

6.1 Introduction

In this chapter, we present and discuss in detail the research methodology adopted for building an automatic animal detection and collision avoidance system. Based on image processing and computer vision techniques, once the animal gets detected in the video (frame), next important step is to find the distance of the detected animal from the camera mounted on the testing vehicle, so that the driver gets an indication of distance (how far or near is the identified animal) of animal from the vehicle and accordingly can apply brakes or take other corrective actions to prevent animal-vehicle collision. Actual implementation and testing of the system with different vehicle speed and different weather conditions is also presented in this chapter.

6.2 Proposed Research Methodology

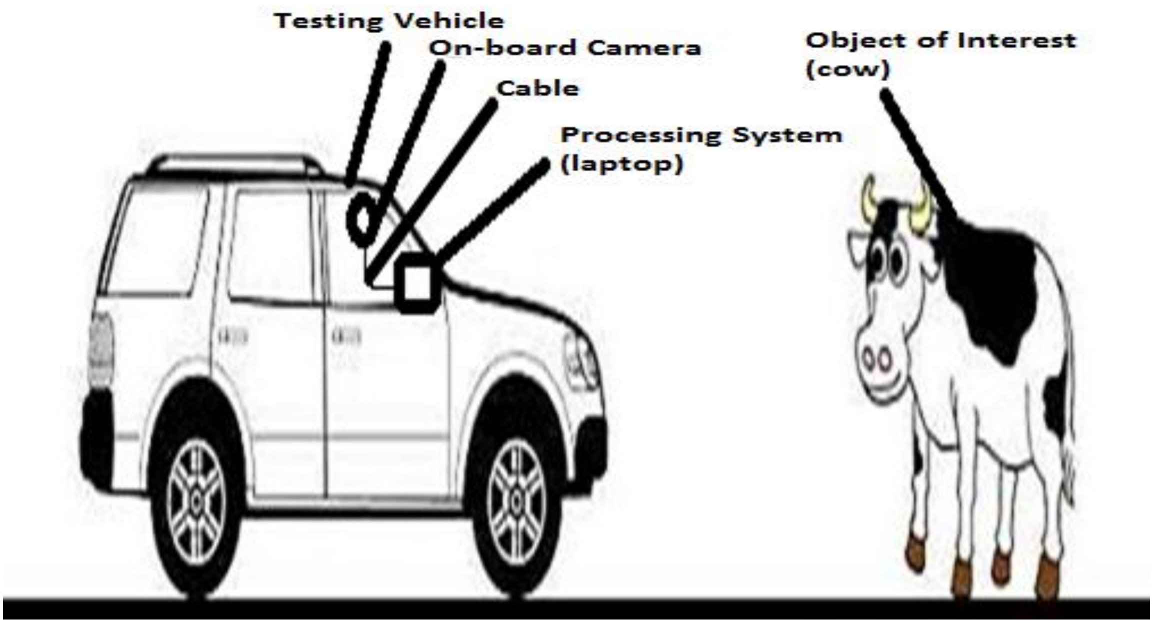

FIGURE 6.1: Rough sketch showing camera mounted testing vehicle with the processing system for automatic animal detection

Figure 6.1 shows the rough sketch of the testing vehicle equipped with on-board camera and the processing system i.e. a computer having animal detection system and display unit with alert (buzzer) indicator also.

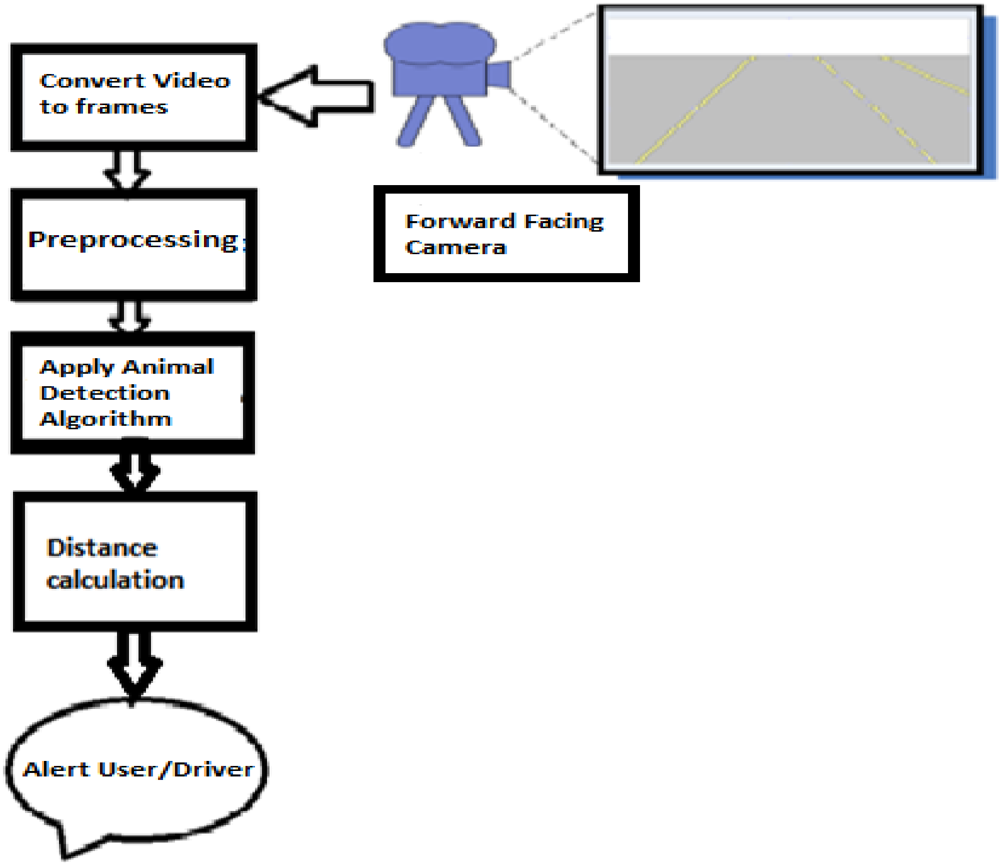

FIGURE 6.2: Block diagram of automatic animal detection and collision avoidance system

Figure 6.2 shows the block diagram of the proposed automatic animal detection and collision avoidance system.Referring to figure 6.2, a video is taken from a forward-facing optical sensor (camera), which is going to capture the objects in front of car, which may have target animal present along with other stationary and non-stationary objects. This video is stored in the computer and then converted into different frames. As the road side video and images are noisy and blurry, we need to perform some pre-processing steps such as noise removal, filtering to enhance the image.

Following the same this frames are feed to the Animal detection system. For feature extraction and learning of the system, we are using a combination of HOG and boosted cascade classifier for animal detection. All the image processing techniques are implemented in OpenCV software. Once the animal gets detected in the video, the next step is to find the distance of the animal from the testing vehicle and then alert the driver so that he can apply the brakes or perform any other necessary action, which is displayed on command prompt as a message. Depending on the distance of the animal from the camera mounted vehicle, three kinds of messages (indication) are given to the driver i.e. animal very near, if animal is very near to the vehicle, animal little far, if the animal is little far from the vehicle and very far, if the animal is very far and at a safe distance from the vehicle.

6.3 Procedure for Training and Testing the Classifier/System

India has more than 20 varieties of cow found in different states of India such as Gir, Sahiwal, Red Sindhi, Sahiwal, Kankrej, Dandi, and others. We have collected and added all the varieties of a cow in the database for training the system. Following is the proposed procedure for training and testing of the data for animal detection:

1. *Collect all positive and negative images in the data folder (figure 5.1 and 5.2).*
2. *Generate Annotation (for visually selecting the regions of interest of the object instances in any given images).*
3. *Create sample i.e. generate .vec file (figure 6.3).*
4. *Train data and generate XML file (figure 6.4 and figure 6.5). Table 6.1 show the parameters used /set during training of the system.*
5. *Testing (figure 6.6).*

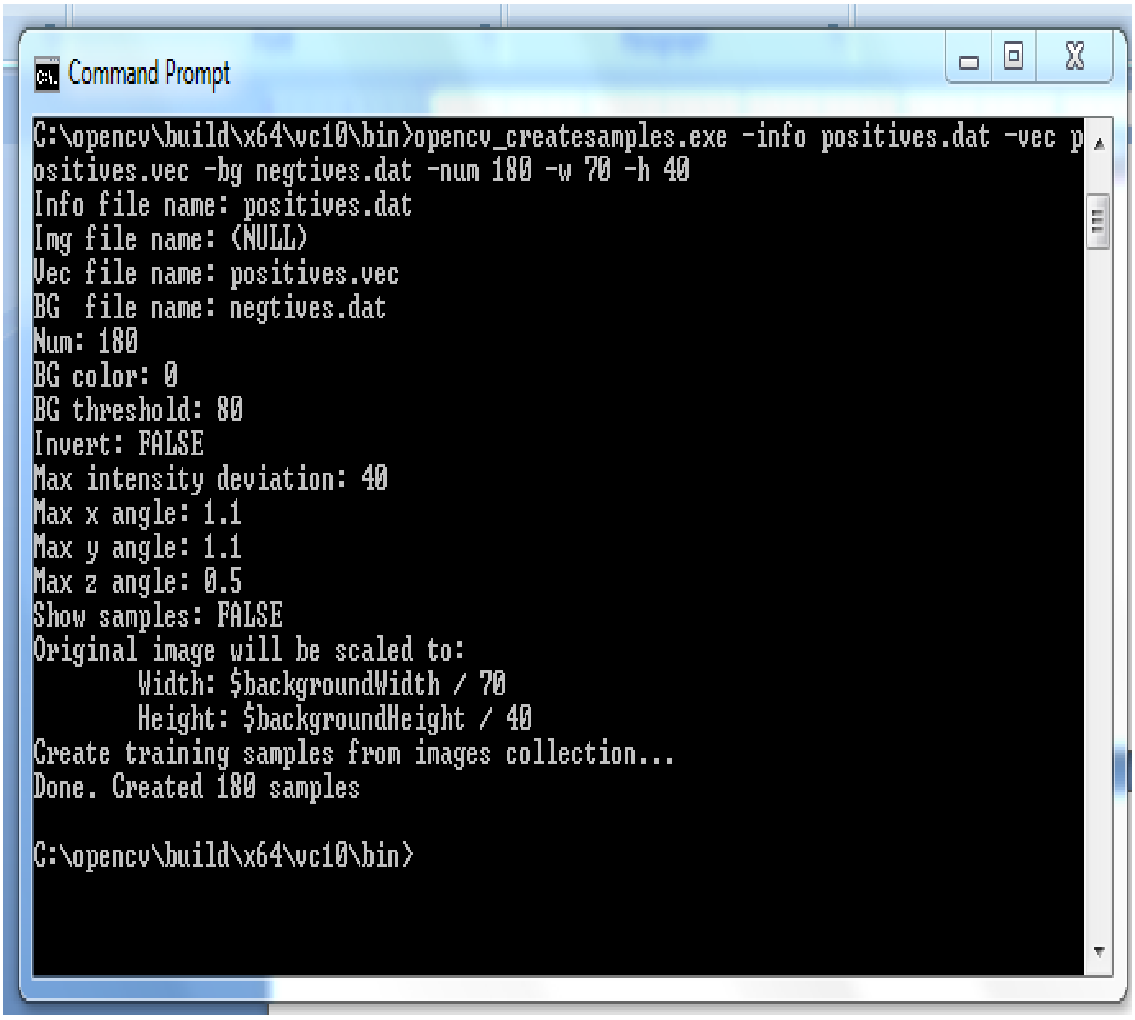

FIGURE 6.3: Creating samples

6.3 Procedure for Training and Testing the Classifier/System

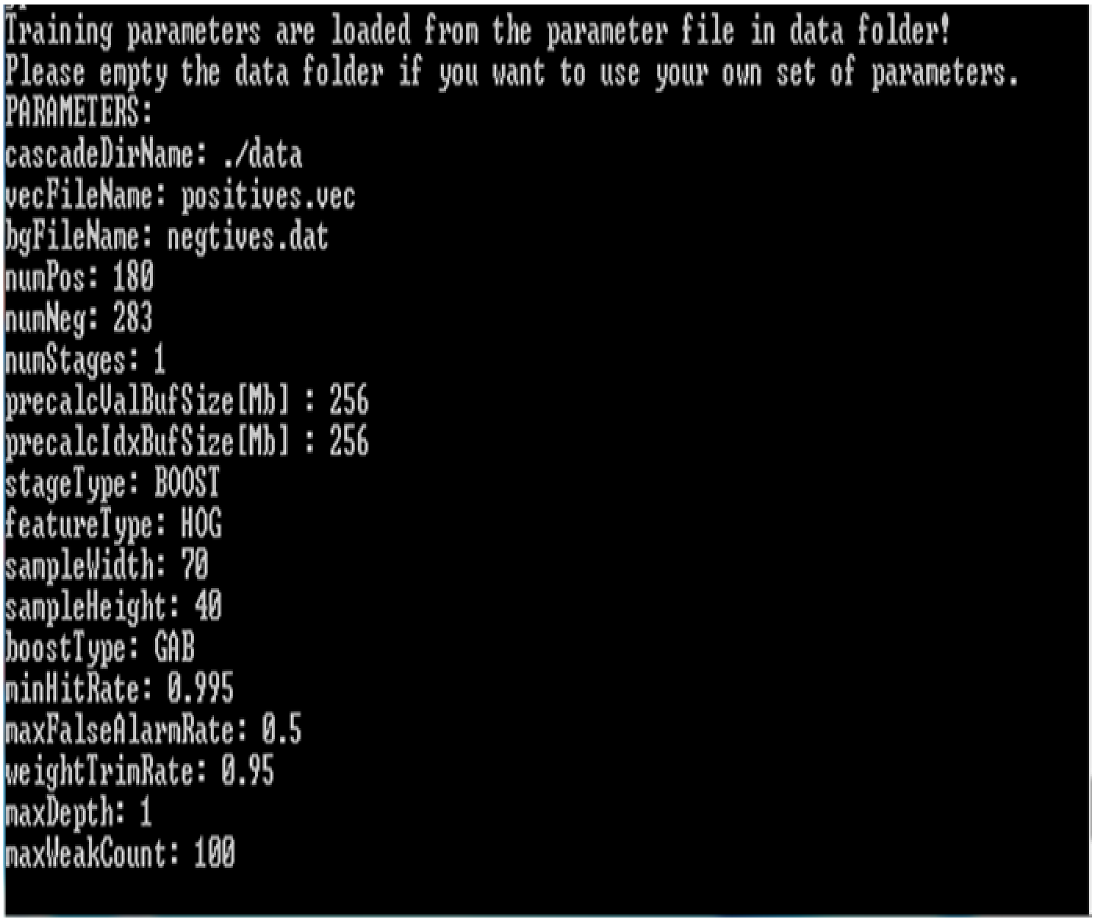

FIGURE 6.4: Training the data

TABLE 6.1: Parameters set up during training of the system

Parameters	Value/Type
numPos (number of positive samples)	700
numNeg (number of negative samples)	1500
numStages (number of stages in cascade)	20

stageType (type of stage in cascade)	BOOST
featureType (feature type for extraction)	HOG
sampleWidth (width)	70 pixels
sampleHeight (height)	40 pixels
boostType (type of boosting)	GAB (Gentle AdaBoost)
minHitRate (minimum hit rate of the classifier)	0.995
minFalseAlarmRate (minimum false alarm rate of the classifier)	0.5

The average time it took to generate a cascade on Intel(R) Core(TM) i5-2430M CPU 2.40GHz, 4GB RAM was almost 14 hours.

```
<?xml version="1.0" ?>
<opencv_storage>
- <cascade>
    <stageType>BOOST</stageType>
    <featureType>HOG</featureType>
    <height>70</height>
    <width>40</width>
  - <stageParams>
      <boostType>GAB</boostType>
      <minHitRate>9.9500000476837158e-001</minHitRate>
      <maxFalseAlarm>5.0000000000000000e-001</maxFalseAlarm>
      <weightTrimRate>9.4999999999999996e-001</weightTrimRate>
      <maxDepth>1</maxDepth>
      <maxWeakCount>100</maxWeakCount>
    </stageParams>
  - <featureParams>
      <maxCatCount>0</maxCatCount>
      <featSize>36</featSize>
    </featureParams>
    <stageNum>30</stageNum>
  - <stages>
      <!--   stage 0   -->
    - <_>
        <maxWeakCount>2</maxWeakCount>
        <stageThreshold>-7.4642084538936615e-002</stageThreshold>
      - <weakClassifiers>
        - <_>
            <internalNodes>0 -1 193 2.5299549102783203e-002</internalNodes>
            <leafValues>8.0689656734466553e-001 -8.8571429252624512e-001</leafValues>
          </_>
        - <_>
            <internalNodes>0 -1 205 2.3257724940776825e-002</internalNodes>
```


FIGURE 6.5: Generating XML file

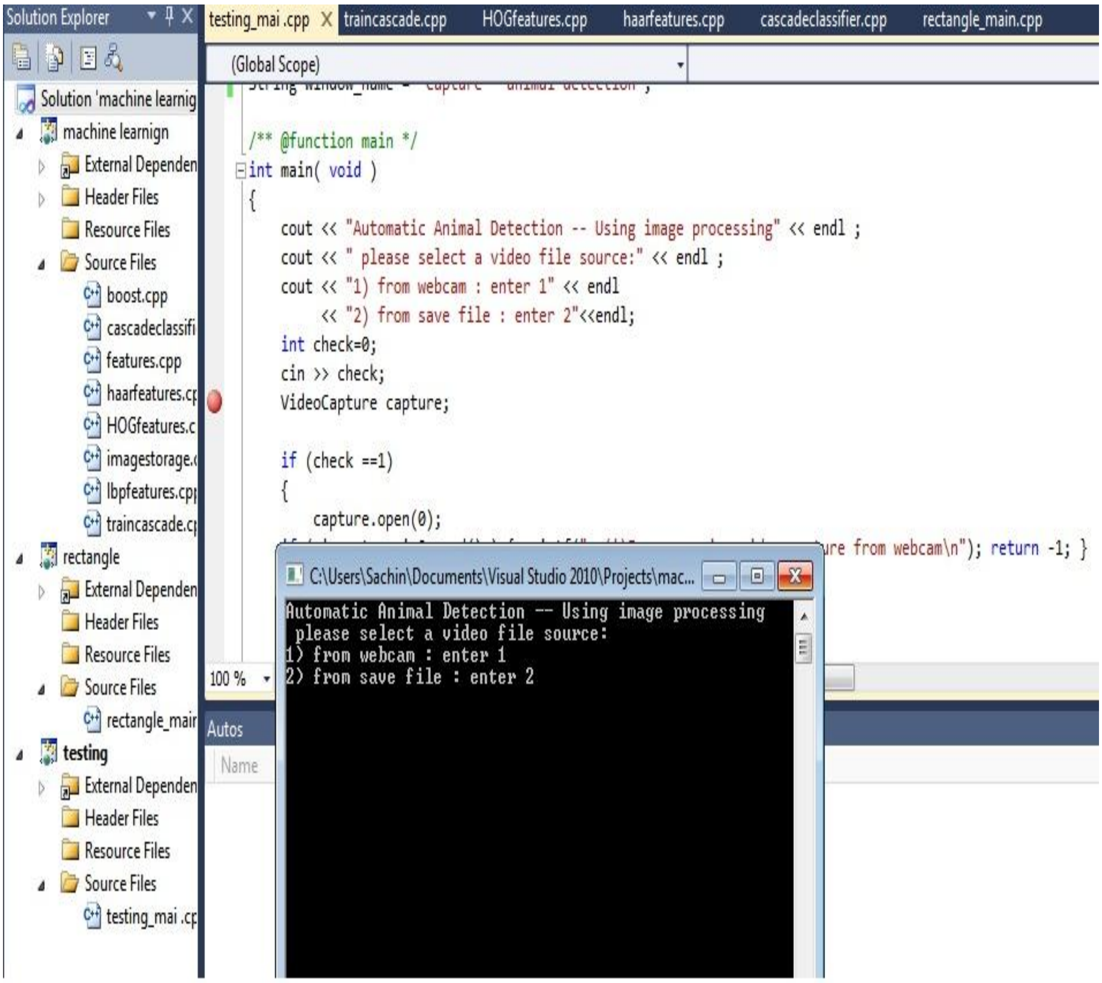

FIGURE 6.6: Testing the system

6.4 Method for Approximate Distance Calculation of the Detected Animal from the Testing Vehicle

Once the animal gets detected in the video (frame), next step is to calculate the distance of the identified animal from the camera mounted on the testing vehicle so that the driver is aware of how far or near the animal is from the vehicle and when to apply brakes or take similar actions to prevent an animal-vehicle collision.

6.4.1 Distance Calculation in Pixels

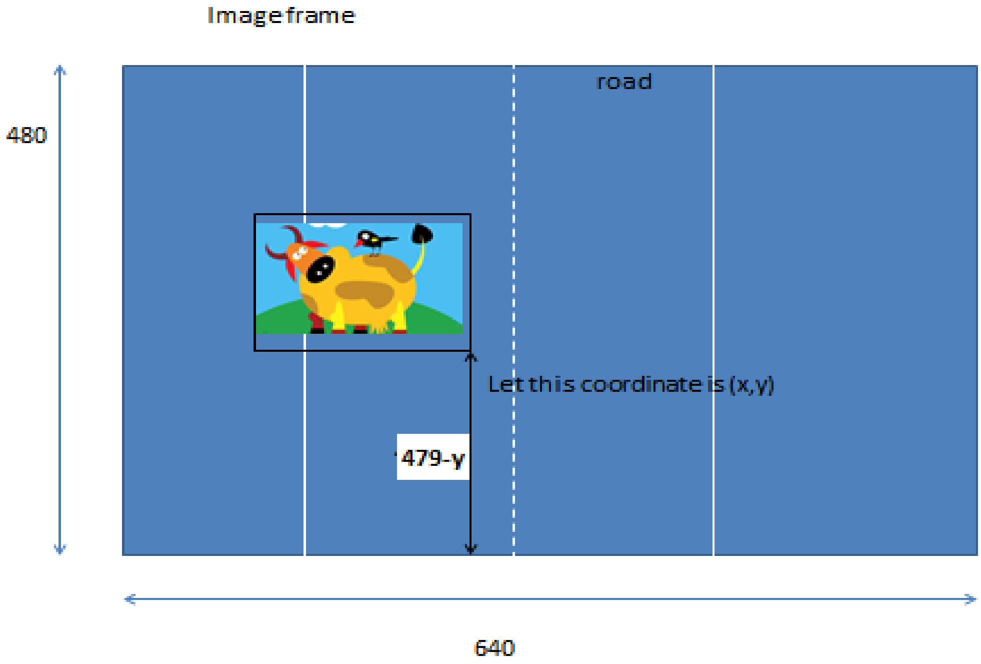

FIGURE 6.7: Distance calculation

As shown in figure 6.7, a video is taken and converted into frames (image of size 640 * 480). Following is the procedure for calculating the distance of the detected animal from the camera-mounted vehicle in pixels:

1. Image resolution is 640 × 480
2. X range is 0 to 639
3. Y range is 0 to 479

Let the right bottom coordinate of the detected cow be (x, y). Then the distance of cow from the lower edge (car/camera) is 479 – y.

Note: The above method of distance calculation works well with the flat ground surface. Suffers a bit if the ground surface is not perfectly flat.

6.4.2 Conversion of Distance from Pixels to Real-World Units

There is some relationship between the depth of the object in pixel and depth in real world units (meters) from the camera mounted vehicle once the object (animal) gets detected in the frame. As the depth of the object in meters from the camera mounted vehicle increases (size of the object decreases), the depth in pixels also increases and vice versa [1]. This hinted us to find a relationship between the depth of the object in pixels and meters. Once the camera position in the car and height of the camera from the ground was fixed (camera calibration done), we took different images of the same object kept at various depths from the camera centre (figure 6.8). The depth of the object from the camera centre in meters was known to us.

We then noted the corresponding depth of the object in pixels. Table 6.2 represents the relation between pixels and meters. Graph of depth in meters versus depth in pixels was plotted in Excel (figure 6.9) and the best fitting second order polynomial equation is

$$y = 0.0323x^2 + 22.208x + 1.3132 \tag{6.1}$$

where y is the depth in pixels and x is depth in meters.

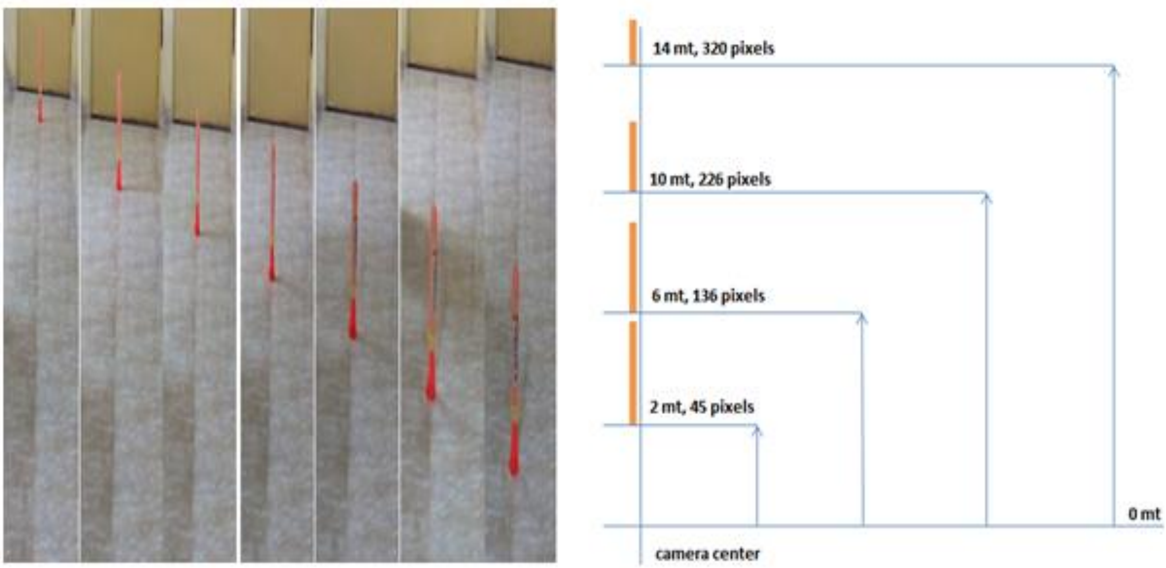

FIGURE 6.8: The same object kept at different positions (depth) from the camera centre

TABLE 6.2: Relationship between pixels and meters

Depth (meter)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Depth (pixel)	23	45	69	91	114	136	159	180	206	226	245	274	295	320

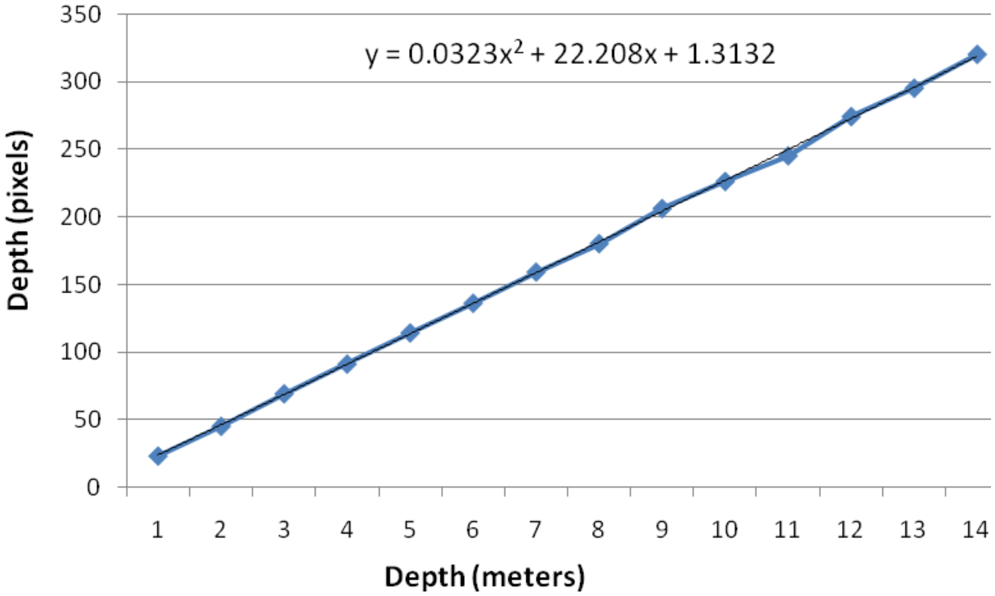

FIGURE 6.9: Graph of depth (meters) versus depth (pixels)

6.4.3 Testing of Actual Distance versus Calculated Distance in Real-World Units

As shown in figure 6.10, we took two images of a cow in which we knew the depth of the cow in meters from the camera-mounted vehicle. We then calculated the depth using the technique as mentioned earlier. Table 6.3 shows the results of actual depth and calculated depth. The error is very less (less than 2 percent).

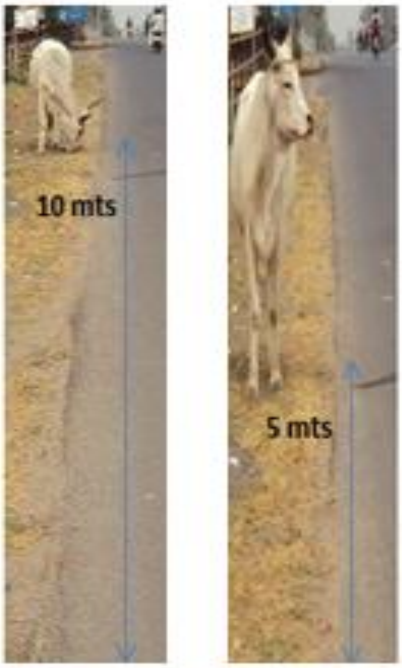

FIGURE 6.10: Testing images (depth in meters was already known)

TABLE 6.3: Actual depth versus calculated depth

Parameters	**Observation 1**	**Observation 2**
Actual depth (meters)	10	5
Calculated depth (meters) after converting from pixels to meters	9.85	4.95
Error in Percentage (%)	1.5	1

6.5 Implementation and Testing the System

We have used HOG descriptors, which are feature descriptors and are used in image processing for the purpose of object detection [2]. For object classification, we have used boosted cascade classifiers. A good source for the animal images is the KTH dataset [3] and NEC dataset [4] that included pictures of cows and other animals. Some more animal images have been clicked (during different weather conditions i.e. morning, afternoon and evening) for creating a robust database of almost 2200 images consisting of positive images in which the target animal is present and negative images in which there is no target animal for feature extraction and for training the classifier. After the classifier is trained and the detection system is built, we tested the same on various videos.

Figure 6.11 shows the camera mounted testing vehicle (experimental setup) with the processing and display system inside the car on the dashboard side.Videos have been taken using a camera having a frame rate of 30fps mounted on the testing vehicle. Hardware used in our experiment is ASUS x53s, Intel(R) Core(TM) i5-2430M CPU 2.40GHz, 4GB RAM. Software used is Microsoft Visual studio 10 Professional, OpenCV 2.4.3, 64 bit operating running under Windows 7. We performed extensive experiments and spent so many hours testing the system in different weather conditions with different vehicle speed on the road.

FIGURE 6.11: Camera mounted testing vehicle

References:

[1] Rahman A, Salam A, Islam M and Sarker P, 2008, An image based approach to compute object distance, International Journal of Computational Intelligence Systems,vol. 4, pp. 304-312.

[2] Dalal N, Triggs B (2005) "Histogram of oriented gradients for human detection", *Proceedings of the 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, New York: IEEE, pp. 63-69.

[3] KTH animal datasets. [Online]. Available: http://www.csc.kth.se/~heydarma/Datasets.html [Accessed 18 June 2013].

[4] NEC animal datasets. [Online]. Available: http://ml.nec-labs.com/download/data/videoembed[Accessed 18 June 2013].

CHAPTER – 7

Results and Discussion

7.1 Parameters for Checking the Performance of the Classifier/System

Parameters which are necessary for testing the performance of the classifier/system are Sensitivity (True Positive Rate), Specificity (True Negative Rate) and Accuracy [1] which are given as

$$Sensitivity = \frac{TP}{TP + FN} \tag{7.1}$$

$$Specificity = \frac{TN}{TN + FP} \tag{7.2}$$

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP} \tag{7.3}$$

Here in above equations, TN stands for true negative; TP stands for true positive; FN stands for false negative; and FP stands for false positive. True positive (TP) and true negative (TN) are the most relevant and genuine parameters of classification. False Positive indicates that the animal is detected in the frame (video) even though the animal is absent in that particular frame at that given location. False Negative (FN) indicates that there is no animal present in the frame (video) even though the animal is present in that particular frame.

7.2 Result Analysis with Different Vehicle Speed and Different Weather Conditions

In our implemented animal detection system, we took 640 frames in which 105 frames are showing animal detected, i.e. marked rectangular box, even though there is no animal present in those frame at those places. So, false positive in this case turns out to be 105 and true negative turns out to be 535. Similarly out of 640 frames, 125 frames are showing no animal detected i.e. no rectangular box even though animals are present in that frame. So false negative turns out to be 125 and true positive turns out to be 515. Substituting the above parameter values in equation (7.1), (7.2) and (7.3), we get sensitivity as 80.4%, specificity of 83.5% and accuracy of the classifier as 82.5%.

Figure 7.1 shows the true positive scenario wherein in the video, animal (cow) is present and our proposed system correctly detects it and gives an indication (box). Similarly, figure 7.2 shows a false positive case wherein animal (cow) is detected in the video by the system even though it is absent in that particular frame at that given location. Figure 7.3 shows a false negative case wherein though the animal (cow) is present in the video; the system indicates absence (no box) of the animal. Figure 7.4 shows animal detected in the morning condition with the experimental camera mounted vehicle stationary i.e. at 0 kmph speed. Figure 7.5 shows animal detected in the afternoon condition with the vehicle speed at 40 kmph. Figure 7.6 shows animal detected in the evening state at a distance of 11 meters from the camera mounted testing vehicle with the vehicle moving at a speed of 60 kmph. Figure 7.7 shows multiple animals detected in one of the testing videos at a distance of 17 meters from the camera mounted vehicle. Training and testing on large datasets will improve the detection rate and accuracy of the classifier.

FIGURE 7.1: True positive case

7.2 Result Analysis with Different Vehicle Speed and Different Weather Conditions

FIGURE 7.2: False positive case

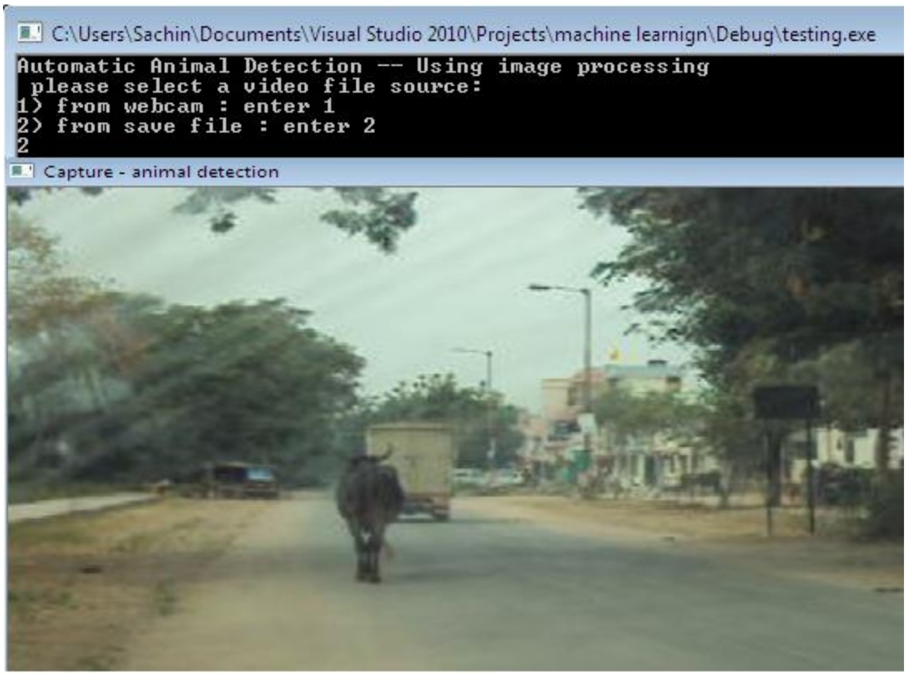

FIGURE 7.3: False negative case

FIGURE 7.4: Animal detection at 0 kmph speed (morning condition)

FIGURE 7.5: Animal detection at 40 kmph (afternoon condition)

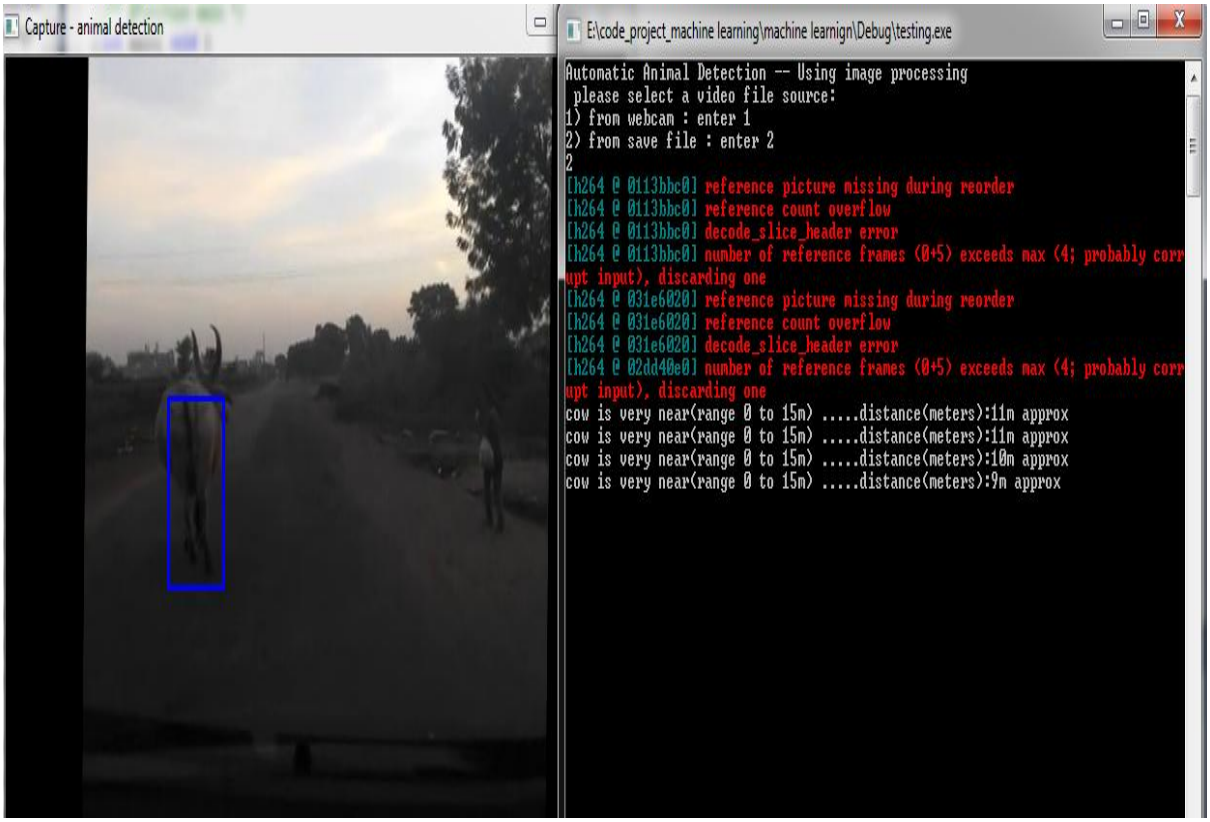

FIGURE 7.6: Animal detected at a distance of approximately 11 meters from the camera mounted vehicle with the speed of 60 kmph (evening condition)

FIGURE 7.7: Multiple animals detected in one of the testing video (detecting distance of 17 meters)

TABLE 7.1: Speed-distance relationship

Vehicle speed (kmph)	**Approximate distance of detection from the camera mounted vehicle (meters)**	**Approximate time available for the response (sec)**
0 (stationary)	20	Enough time to avoid collision as maximum speed of Indian cows

		is 3 to 3.5 kmph [2]
20	18	3.24
30	17	2.04
35	17	2.04
40	15	1.35
50	14	1.00
60	11	0.66

The average processing (computation) time with our proposed image processing method is 100ms (10 frames per second) which can be still be shortened using Nvidia's CUDA processor. According to the article [3], the term response time or brain reaction time of the drivers in traffic engineering literature is composed of mental processing time, movement time and mechanical response time. As per the "two-second rule" which is usually a rule of thumb suggests that a driver should ideally stay at least two seconds behind any object that is in front of the driver's vehicle [4]. The two-second rule is useful as it can be applied to any speed and provides a simple and common-sense way of improving road safety. So if we go with "two-second rule", clearly from Table 7.1 (speed-distance relation as well as actual time (on-board) available for the driver to responds), it indicates that when the speed of the vehicle is between 30 to 35 kmph, the driver gets some time to apply brakes and can avoid a collision. Anything above this speed, though the alert signal is available, the driver won't be able to avoid a collision.

7.3 Comparison of HOG-Cascade and Haar-Cascade Classifier Test Results

Comparison of HOG-Cascade classifier with another popular feature descriptor i.e. Haar-Cascade classifier is shown in Table 7.2. ROC (receiver operating characteristic) curve, which is a graphical plot that illustrates the performance of a classifier system as its discrimination threshold is varied, is shown in figure 7.8 for the hog-cascade classifier and haar-cascade classifier. The curve is created by plotting the true positive rate (TPR) against the false positive rate (FPR) at various threshold settings.

Apparently, the algorithm based on hog-cascade classifier gives good results compared to haar- cascade classifier.

TABLE 7.2: Set of tests by cascade classifier

Feature descriptor	TP	FP	TN	FN	Sensitivity	Specificity	Accuracy	Average Processing Time (ms)
HOG	515	105	535	125	80.4%	83.5%	82.5%	100ms
Haar	502	142	498	138	78.4%	77.8%	78.1%	150ms

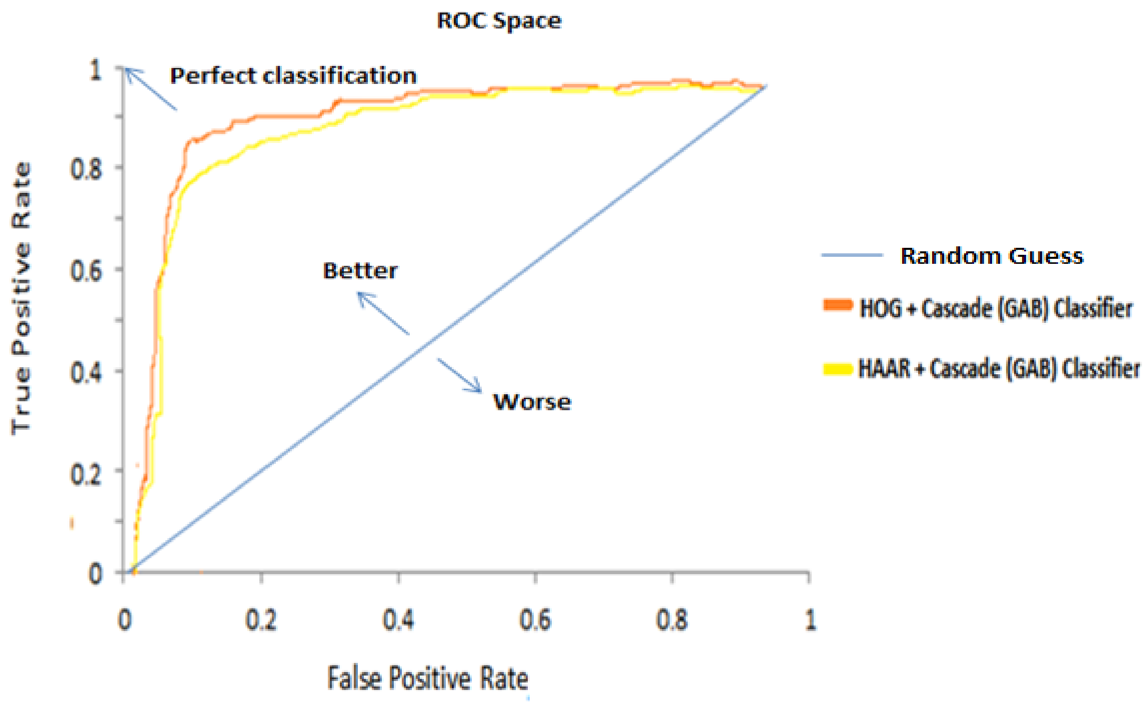

FIGURE 7.8: ROC curve

References:

[1] Gupta N, Rawal A, Narasimhan V and Shivani S, 2013, Accuracy, Sensitivity and Specificity measurement of various classification techniques on healthcare data, IOSR Journal of Computer Engineering (IOSR-JCE), vol. 11, pp. 70-73, ISSN: 2278-0661.

[2] Singh G (1999) "Draught animal energy research in India", *Proceedings of Animal Traction Network for Eastern and Southern Africa (ATNESA)*, South Africa, pp. 315-322.

[3] Car accidents and brain reaction time accidents. [Online]. Available: http://www.chaikinandsherman.com/Car-Accidents/Brain-Reaction-Time-Accidents.aspx [Accessed 5 May 2016].

[4] Information on safe following distances between vehicles. [Online]. Available: https://www.qld.gov.au/transport/safety/rules/road/distances[Accessed 5 May 2016].

CHAPTER – 8

Conclusion, Objectives Achieved and Possible Further Work

8.1 Conclusion

This thesis addressed several challenging issues related to automatic animal detection on highways. An efficient automatic animal detection and an alert system can help drivers in reducing the number of collisions occurring between the animal and the vehicle on roads.

In this thesis, we discussed the necessity and importance of automatic animal detection system on roads and presented our approach/algorithm based on HOG and boosted cascade classifier for automatic animal detection. The algorithm can detect an animal (cow) in different weather conditions on highways. Considering the complexities involved in identifying animal on roads wherein apart from moving or stationary animal of interest, there are other objects also like vehicles, pedestrians, shadows of trees and other objects which makes animal detection very hard, the proposed system achieves an accuracy of almost 82.5 % in terms of animal (cow) detection. Estimation of approximate animal distance from the testing vehicle is also done. Though the proposed work has been focused on automatic animal detection in context to Indian highways it will work in other countries also. The proposed method can easily be extended for detection of other animals too after proper training and testing. The proposed system can be used with other available, efficient pedestrian and vehicle detection systems and can be offered as a complete solution (package) for preventing collisions and loss of human life on highways.

8.2 Objectives Achieved

Following objectives were met while trying to achieve the primary goal of providing low-cost automatic animal detection on highways:

1. Algorithm developed is working properly and able to detect an animal in different conditions on roads and highways.

2. Estimation of animal distance from the testing vehicle is done. Maximum detecting distance of the animal from the camera mounted vehicle was found to be 20 meters.

3. Speed analysis (different speeds like 20, 30, 35, 40, 50, 60 kmph) is implemented and tested.

4. Alert signal to the driver is available.

8.3 Limitations

Though our proposed system can detect the animals (cow) on roads and highways as well as gives alert to the driver, it has some limitations too. The proposed system can detect animal up to a distance of 20 meters only when a vehicle or object is stationary. The system can prevent collision of the vehicle with the animal when driving at a speed in between 30 to 35 kmph. Beyond this speed, though animal gets detected but response time may not be sufficient to prevent animal-vehicle collision.

8.4 Possible Further Work

1. Some means or method of increasing the detecting distance of the animal from the camera mounted vehicle needs to be studied so that driver gets sufficient time for applying brakes or take any other action for preventing the collision which may be solved using high-end resolution cameras with high processing rate or radar or using some CUDA processor.

2. No effort has been made to detect animals on the roads and highways during the night condition, which needs to be studied.

Appendix A:

Calculation of parameters for verifying the performance of classifier/system

Parameters which are necessary for checking the performance of the classifier/system are Sensitivity (True Positive Rate), Specificity (True Negative Rate) and Accuracy which are given as

$$Sensitivity = \frac{TP}{TP + FN} \tag{1}$$

$$Specificity = \frac{TN}{TN + FP} \tag{2}$$

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP} \tag{3}$$

Here in above equations, TN stands for true negative; TP stands for true positive; FN stands for false negative; and FP stands for false positive. True positive (TP) and true negative (TN) are the most relevant and true parameters of classification. False Positive indicates that the animal is detected in the frame (video) even though the animal is absent in that particular frame at that given location. False Negative (FN) indicates that there is no animal present in the frame (video) even though the animal is present in that particular frame.

In our implemented animal detection system, we took 640 frames in which 105 frames are showing animal detected i.e. rectangular box even though there is no animal present in those frame at those places. So, false positive in this case turns out to be 105 and true negative turns out to be 535. Similarly out of 640 frames, 125 frames are showing no animal detected i.e. no rectangular box even though animals are present in that frame. So false negative turns out to be 125 and true positive turns out to be 515.

So, substituting TP = 515, TN = 535, FP = 105, FN = 125 in equation (1) (2) and (3), we get

$$Sensitivity = \frac{TP}{TP+FN} \times 100$$

$$= \frac{515}{515+125} \times 100$$

$$= 80.4\%$$

$$Specificity = \frac{TN}{TN+FP} \times 100$$

$$= \frac{535}{535+105} \times 100$$

$$= 83.5\%$$

$$Accuracy = \frac{TN+TP}{TN+TP+FN+FP} \times 100$$

$$= \frac{535+515}{535+515+125+105} \times 100$$

$$= 82.5\%$$

List of Publications

In International Journals:

1. S. Sharma and D. Shah "A Practical Animal Detection and Collision Avoidance System Using Computer Vision Technique", IEEE Access Journal, IEEE, vol 5, pp. 347-358, December 2016 (Impact Factor: 1.27 calculated according to Journal Citation Reports, Thomson Reuters).

2. S. Sharma and D. Shah "Real-Time Automatic Obstacle Detection and Alert System for Driver Assistance on Indian Roads", International Journal of Electrical and Computer Engineering, IAES Publishers, vol 1, No.3, pp. 635-646, March 2016 (Scopus Indexed).

3. S. Sharma and D. J. Shah "Design and Development of an Imaging System for Animal Detection on Highways", Journal of Experimental & Theoretical Artificial Intelligence, Taylor and Francis (Impact Factor: 1.79 calculated according to Journal Citation Reports, Thomson Reuters). Paper accepted with minor revisions.

In International Conferences:

1. S. Sharma, D. Shah and R. Bhavsar "Computer Assisted Intelligent Highway Safety & Alert System in Relation to Indian Scenario using LabVIEW", 2015 Sixth International Conference on Recent Trends in Information , Telecommunication and Computing – ITC 2015, Chandigarh, February 14 -15, 2015 (McGraw-Hill Education Professional (Scopus Indexed Conference as well published in International Journal of Computer Theory and Engineering (GIJCTE))

2. S. Sharma, D. Shah and R. Bhavsar " Automated Detection of Animals in Context to Indian Scenario", 2014 Fifth International Conference on Intelligent Systems, Modelling and Simulation, Malaysia, pp. 334-338, January 2014 (IEEE Conference).