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Real-Time Automatic Obstacle Detection and Alert System for Driver Assistance on Indian Roads

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Abstract

Road crashes have been a major problem in India in recent times. The occurrences have increased considerably owing to the influx of four-wheelers and two-wheelers on Indian roads. The number of road traffic collisions has also increased due to the absence of automatic highway safety and alert systems on major roads connecting cities and towns. The interior roads connecting villages and towns have been instrumental in multiple animal-vehicle collisions. Although the figure is not too large compared to other causes of road-related injuries, they are significant in number. The associated number of fatalities and injuries are substantial too. Though numerous efforts have been in progress to solve and reduce the number of collisions, lack of practical applications and resources along with quality analytical data (for training and testing) related to animal-vehicle collision has impeded any major breakthrough in the scenario. In our current work, we have proposed and designed a system based on histogram research including oriented gradients and boosted cascade classifiers for automatic cow detection. The Indian cow has been the biggest obstacle compared to other animals on Indian roads. The distance between a cow and the vehicle is calculated prompting an alert signal to notify the driver for applying brakes or undertake any similar action. The method is implemented in Opencv software and tested on various video clips involving cow movements in various scenarios. The proposed system has achieved an overall efficiency of 80% in terms of cow detection. The proposed system is a low-cost, highly reliable system which can easily be implemented in automobiles for detection of cow or any other animal after proper training and testing on the highway.

Keywords*: Animal detection system; Cascade classifier; Histogram of oriented gradient; Intelligent highway safety; Road accidents*

1. Introduction

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 of 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 main 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 collisions and traffic accidents remain as high as 1.24 million per year [2]. By 2020, the road traffic fatalities are projected to increase by around 65% globally [3]. In a country like India, 1 in 20,000 people die and 12 in 70,000 people sustain serious injuries every year due to road accidents [4].

India has the second largest road network in the world and is also known for the highest number of road accidents and fatalities in the world [5]. Data published by the National Crime Records Bureau (NCRB), Ministry of Home Affairs, Government of India, shows that road accident fatalities have been steadily rising each year and in year 2008, there were 118,239 fatalities due to road accidents [6]. A significant portion of these road crashes and accidents involve cars and two-wheelers.

The road accidents are increasing due to increase in number of vehicles on the road 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 almost 10% of the total road accident deaths in the world. According to the accident research study conducted by JP

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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].

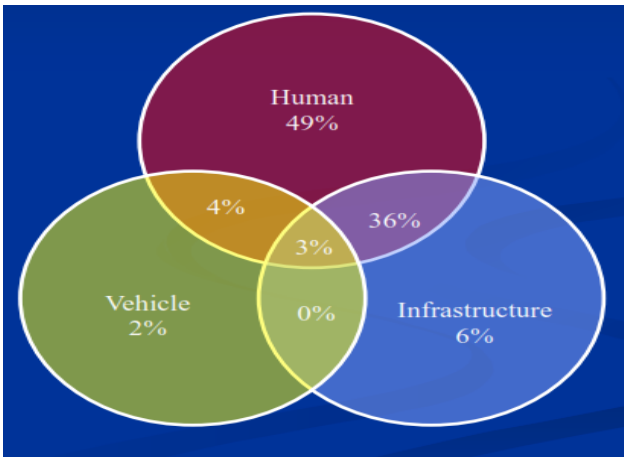

Figure 1. Influences on road traffic accidents

The number in the figure 1 is 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 (animal) on the road, driver inattention and absence of an intelligent highway safety alert system.

2. Literature Survey

Applications based on animal detection have an important role in providing solutions to many real-life problems. Some of these applications are detect and track animals like elephants in forests for understanding their behavior with the environment, preventing animal vehicle collision on roads, and for preventing the entry of dangerous animals in a residential area [9]. The base for most of the applications is the detection of animals in the video or image. Many applications require human intervention.

A recent study [10] recently also revealed that human beings need to take the final decision during driving whether they can control their car to prevent collision with a response time of 150ms. The problem with this method is that human eyes get tired easily and need some rest consistently which is why this method is not that effective. Researchers in [11] revealed a technique for the identification of salamanders by dorsal skin patterns. This technique reveals key points along the skeleton of the animal to be labelled physically (manually) by the user. Similar user input [12] is required for the detection and identification of elephants from the ear profile.

Some scientific researchers [13] have categorized animals using an arrangement with a still camera mounted at one side of a strip (corridor). This arrangement makes the detection of animals passing the strip (corridor) trivial. Some methods [14] need the animals to strike a particular angle or a pose towards the camera for the trigger, including face detection. A popular clue for the detection of animals is motion. The fundamental hypothesis here [15] is that the default position is stationary and can simply be subtracted. All blobs which remain after background subtraction are considered as region of interest (candidate) detections. Though this works fine in restricted areas, e.g., for underwater videos, such mechanism does not hold in general settings.

Researchers [16] used threshold segmentation approach for getting the targeted animal's details from background. Recent researches [17] also revealed that it is difficult 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 [18] and [19]. The tracking light (sparse) features points over time and applies RANSAC to separate background & foreground motion. The background motion is taken as the main (dominant) motion in the scene. The rest of the motion is taken as a single object which can be the animal/ obstacle of interest. The problem with this method is that other moving objects would disturb the approach and may be falsely detected as animals.

Researchers in [20] 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 method would involve gigantic amount of image processing in a short period of time [21]. Some researchers [22] proposed a method for animal species detection and made similar restrictions regarding the foreground objects in the video. The drawback of this proposed method was that it was highly specific to the specific setting and not valid in the context of the Indian roads where several animals may be present at the same time.

Researchers in [23] also used the face detector technique initiated by Viola and Jones for a specific animal type. Once an animal face is detected and identified, the researchers try to track it over time. The problem with this technique is that face detection needs the animals to look into the camera which is, in general, not necessarily captured by the road travel video. Animals can arrive from a scene from various directions and in various sizes, poses and colors. An interesting approach for the animal detection and tracking uses a texture descriptor based on SIFT that tries to match it against a predefined library of animal textures [24]. The problem with this method is that it is restricted to videos having single animal only and very minimal background clutter. Both conditions are not met especially with animals present on road sides.

In Saudi Arabia, the number of collisions between the camel and a vehicle were estimated to reach more than a hundred each year. To prevent these collisions, an intelligent Camel Vehicle Accident Avoidance System (CVAAS) was designed using GPS (global positioning system) [25]. For finding the correct position of fishes in the sea, researchers [26] designed a technique using LIDAR (light detection and ranging). Using the micro-Doppler technique [27], researchers also tried avoiding risky animal intrusions in the housing area.

Lack of resources and quality database of images (for training and testing) of animals on the road is still one of the challenging tasks. Due to this fact and as per our latest surveys, very less work has been reported so far in this area at least in context to Indian highways. In this paper, we present a novel approach for the detection of animals (cow) on Indian roads and a method for calculating the distance of detected animal from the camera mounted vehicle (after detection) which can help the driver to avoid the collision vehicle-animal collision.

Intelligent highway safety and driver assistance systems are very helpful to reduce the number of accidents that are happening due to vehicle-animal collisions. With respect to Indian roads, two types of animals – the cow and the dog are found more often than others on the roads. Specific objectives of the research work are:

- To develop an automatic animal detection system in context to Indian roads.
- Finding the approximate distance of animal from the vehicle in which camera is mounted.
- To develop an alert system once the animal gets detected on the road which will help the driver in applying brakes or taking other necessary action for avoiding collision between vehicle and animal.

3. Brief Overview and Advantages of HOG and Cascade Classifier

A histogram of oriented gradients (HOG) is actually a feature descriptor used to detect objects in computer vision and image processing [28]. The HOG descriptor technique recounts occurrences of gradient orientation in localized portions of an image - detection window, or region of interest (ROI). Figure 2 shows the algorithmic implementation scheme of HOG.

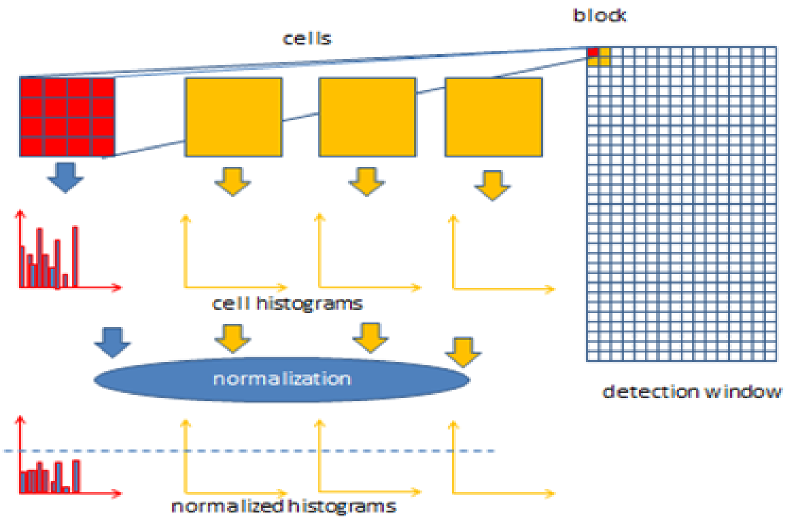

Figure 2. Algorithmic implementation scheme of hog

The HOG descriptor is particularly appropriate for animal detection or human detection in video or images due to some key advantages compared to other descriptors. First, it operates on local cells so it is invariant to geometric and photometric transformations. Secondly coarse (spatial) sampling, fine orientation sampling and strong local photometric normalization allow individual body movement of animals/pedestrians to be overlooked if they maintain a roughly upright position [29].

Cascading is a particular case of group learning based on the concatenation of several classifiers, using all information collected from the output from a given classifier as additional information for the next classifier in the cascade [30]. 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 candidates (false positives) early on, so later stages don't bother about them.

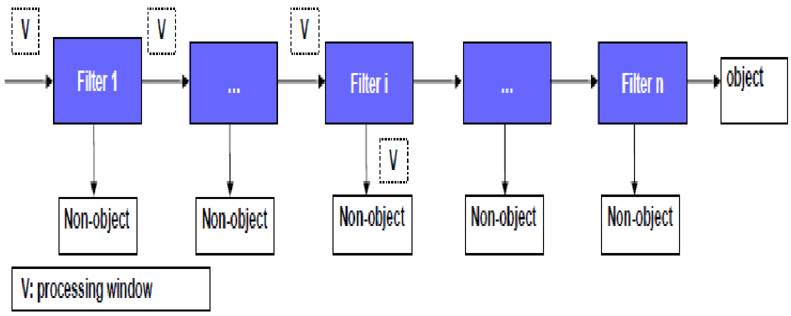

Figure 3. Boosted cascade classifier

As shown in the figure 3, each filter rejects non-object windows and let object windows past to the next layer of the cascade. A window is considered as an object if and only of all layers of the cascade classifies it as object [31]. The filter i of the cascade is designed to

- Reject the large possible number of non-object windows
- To allow large possible number of object windows for quick evaluation

4. Research Methodology

As shown above in Figure 4, a video is taken from a forward-facing camera in which a moving animal is present apart from other stationary and non-stationary objects. This video is stored in the computer and converted into different frames. We are using a combination of HOG and boosted cascade classifiers for animal detection. All the image processing techniques are implemented in Open CV 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.

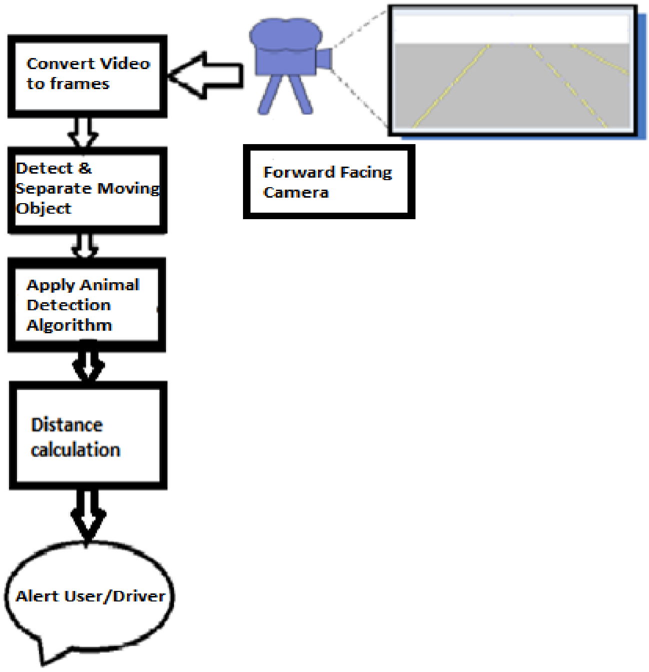

Figure 4. Block diagram of the proposed method

Following is the proposed procedure for training and testing of the data for animal detection:

- Collect all positive and negative images in the data folder
- Generate Annotation
- Create sample i.e. generate .vec file (figure 5)
- Train data i.e. generating xml file (figure 6, 7)
- Testing (figure 8)

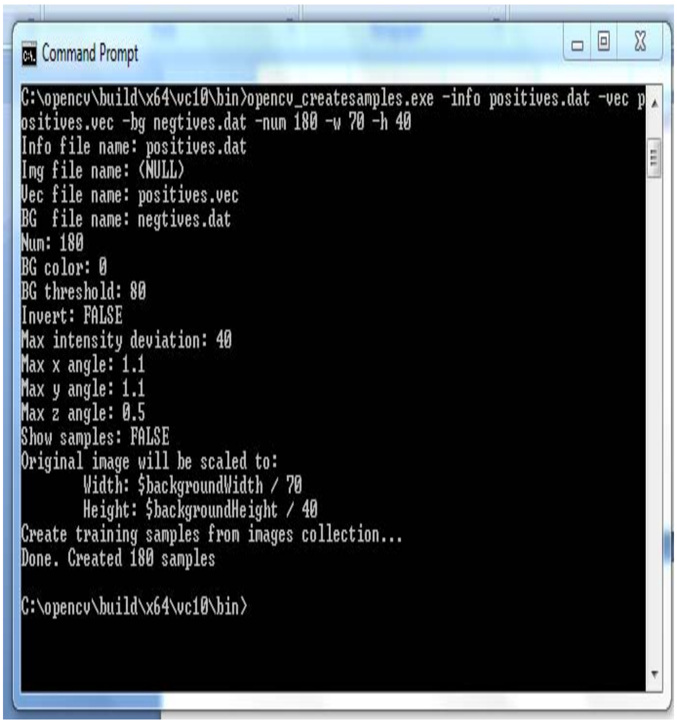

Figure 5. Create sample

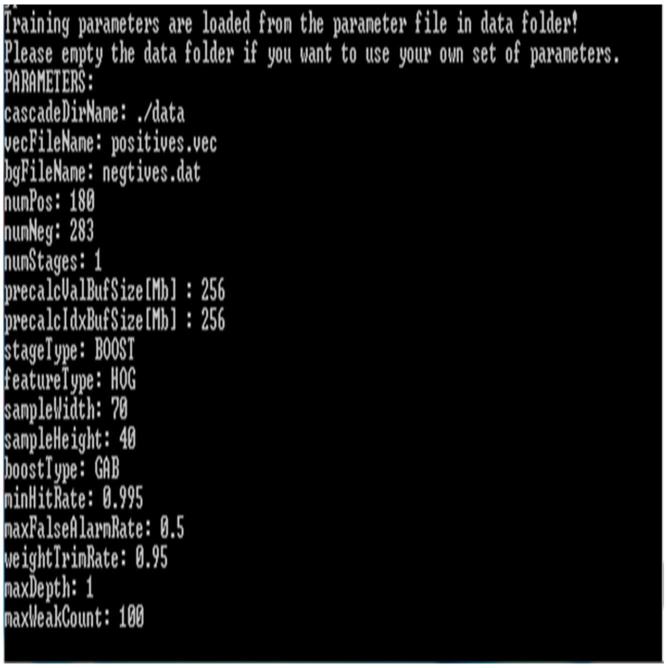

Figure 6. Train data

```
<?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 7. XML file

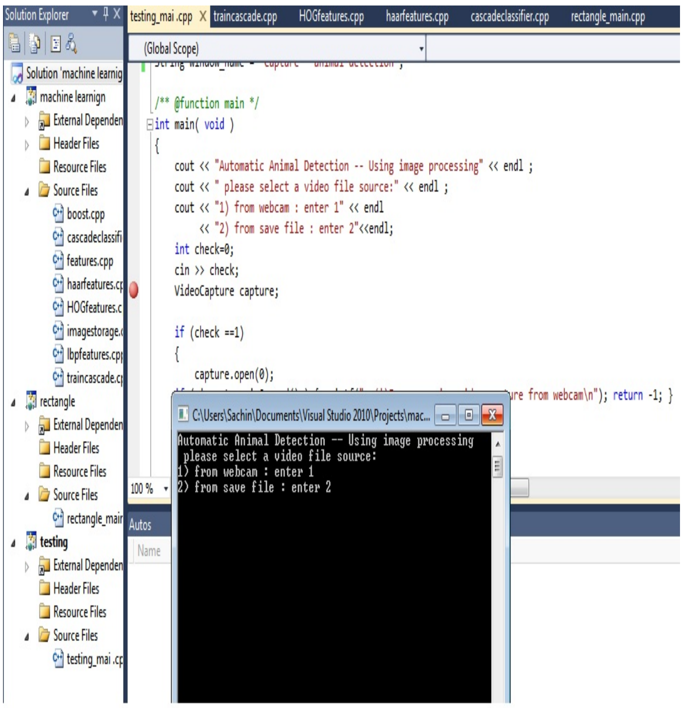

Figure 8. Testing

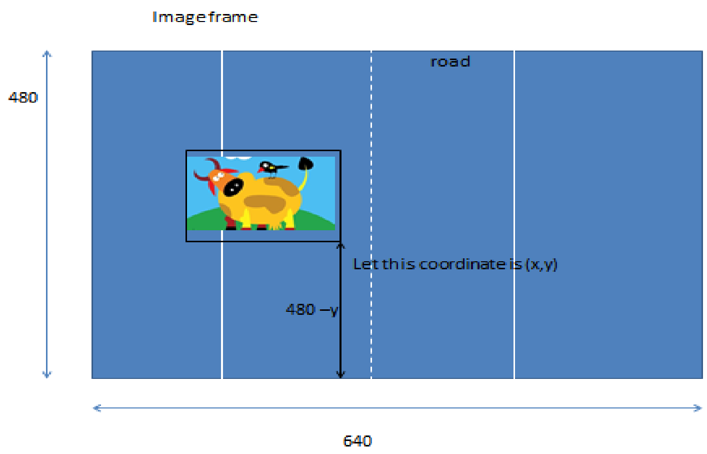

Figure 9. Distance calculation

As shown in the figure 9, 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:

- Image resolution is 640 × 480
- X range is 0 to 640
- Y range is 0 to 480
- Let the right bottom coordinate of the detected cow be (x, y)
- Then the distance of cow from the lower edge (car/camera) is 480 – y

5. Data Analysis and Interpretation

We are using HOG descriptors which are feature descriptors and are used in computer vision and image processing for the purpose of object detection. For object classification, we are using boosted cascade classifiers. For preparing the required database, we are performing animal detection in relation to the Indian scenario as no research has been performed till date in this area, and not many sources are present related to this scenario. A good source for the animal images is the KTH dataset [32] and NEC dataset [33] that included images of cows and dogs (of our interest). Some more animal images have been clicked for creating a healthy database of almost 900 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. We tested our method on at least 28 to 30 videos (frames of size 640*480), including 80 animals (cow) in the video. A detection rate of almost 80% was achieved with low false detection rate in case of single object (cow) in the frame (testing video). Training and testing on large datasets with different orientations and different weather conditions will improve the detection rate and overall efficiency of the system.

Some of the screenshots of the camera-mounted vehicle and results (with different climate conditions and with different speeds) are shown in figures 10, 11, 12, 13, 14 and 15.

Figure 10. Camera mounted vehicle

Figure 11. Animal detection at 0 kmph speed with object stationary in morning condition

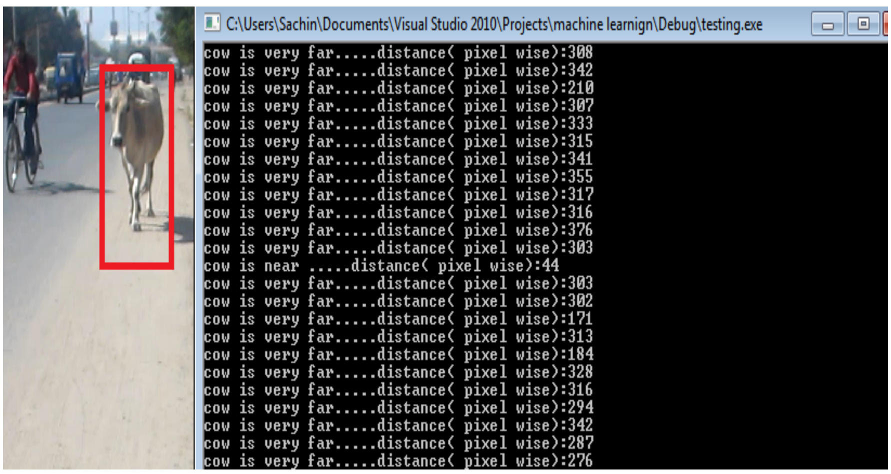

Figure 12. Animal detected at a speed of 40 kmph in afternoon condition

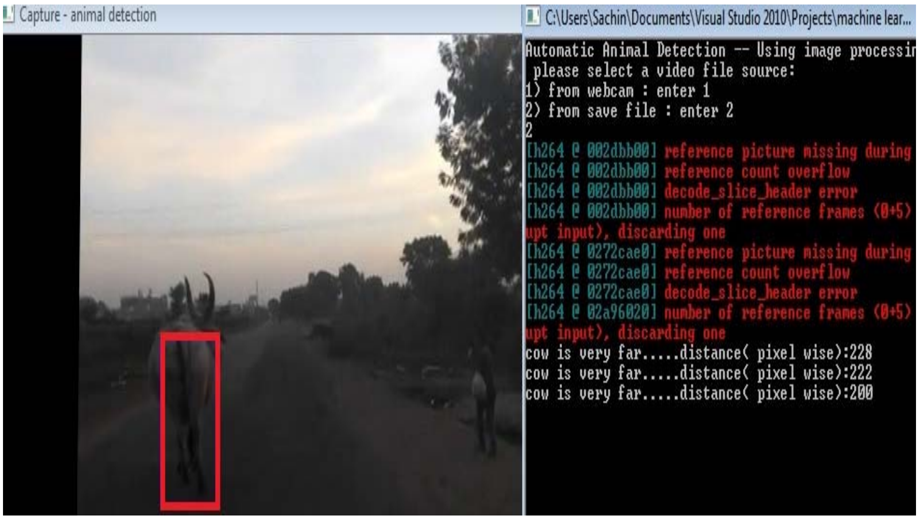

Figure 13. Animal detected at a distance of 228 pixels from the camera mounted vehicle with the speed of 60 kmph in evening time

Figure 14. Multiple animals detected in one of the testing video

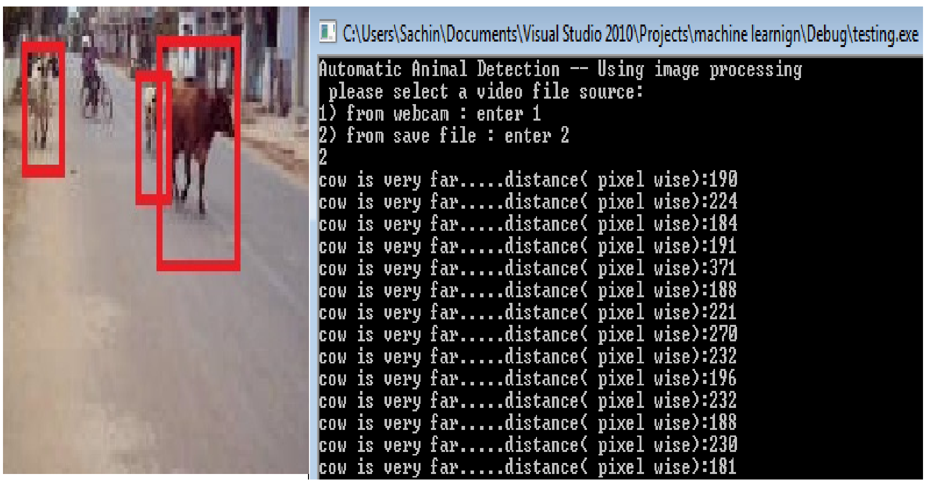

Figure 15. Multiple animals detected in the second testing video

6. Conclusion and Future Work

An efficient automatic animal detection and alert system can help drivers in reducing the number of collisions occurring between the animal and the vehicle on roads and highways. In this paper, we discussed the necessity of automatic animal detection system and our algorithm for animal detection based on HOG and cascade classifiers. The algorithm is able to detect animal in different conditions on Indian roads. Estimation of animal distance (in pixels) from testing vehicle is also done. The conversion of pixel to meters can be done using proper camera calibration method which is to be done in future scope. Speed analysis with different speeds like 30, 40, 50 and 60 kmph is implemented and tested. The proposed method can be extended for detection of other animals too.

Training and testing on large datasets is yet to be done to improve the efficiency of the system in animal detection. The assessment of the direction in which the animal is proceeding is yet to be performed satisfactorily. No effort has been made to detect animals during the night, which is expected to be done in our future scope of study and research.

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