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Vehicle-camel collision avoidance system in Libyan desert roads using computer vision technique

*Salem Alsaid[a], Hisham AbouGrad[b], Ahmed Abubahia[c] , Naeima ali[a]

[a]Department of Communications & Computer Networks, College of Information Technology, Sebha University, Libya Computer Science & Digital Technologies
[b] Department of Computer Science and Digital Technologies School of Architecture, Computing and Engineering ,University of East London, EB.1.99, University Way, Docklands, London, E16 2RD, UK
[c] School of Science, Technology & Health York St John University, Lord Mayor's Walk, York, YO31 7EX

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ABSTRACT

Travelling across the desert roads in Libya is faced with a major challenge represented by the spread of camels along these roads. Stray camels crossing these roads have caused countless accidents, many of them were unfortunately reported as fatal. Conventional solutions such as road signs, wildlife warnings and fencing the highway sides are either ineffective, expensive or inadequate. In this paper, a simple and low-cost automated system is proposed to detect the presence of an animal on the road to alert the vehicle's driver and hence preventing the vehicle-animal collision. Using image processing and computer vision techniques, the suggested system provides a method for determining the distance of the animal from the vehicle using a camera setup. More specifically, the Histogram of Oriented Gradients (HOG) scheme is used in this work as a feature descriptor for the purpose of object (animal) detection. Through Matlab simulation, the system is trained via positive and negative images of camels on highways. To validate the results even more, the proposed system is examined in various weather conditions in the targeted desert roads of Libya and the results have shown that it was able to distinguish the presence of animals with high accuracy.

نظام تجنب إصطدام المركبات بالإبل في الطرق الصحراوية الليبية بإستخدام الرؤية الحاسوبية

*سالم الصيد[1] و هشام أبو جراد[2] و أحمد أبوباهيه[3] و نعيمة علي[1]

[1] قسم الاتصالات وشبكات الحاسوب، كلية تكنولوجيا المعلومات، جامعة سبها، ليبيا علوم الحاسوب والتقنيات الرقمية
[2] قسم علوم الكمبيوتر والتكنولوجيا الرقمية كلية الهندسة المعمارية والحوسبة والهندسة، جامعة شرق لندن، *EB.1.99*، *University Way*، دوكلاندز، لندن، *E16 2RD*، المملكة المتحدة
[3] كلية العلوم والتكنولوجيا والصحة جامعة يورك سانت جون، لورد مايور ووك، يورك، *YO31 7EX*

الكلمات المفتاحية:
تجنب الإصطدام
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إصطدام المركبات بالإبل.

الملخص

يواجه المسافرون عبر الطرق الصحراوية في ليبيا تحدياً كبيراً يتمثل في انتشار الإبل على هذه الطرق. فقد تسببت الإبل الضالة لطريقها والعابرة لهذه الطرق في وقوع عدد لا يحصى من الحوادث المميتة. الحلول التقليدية السابقة كعلامات التحذير وتسييج جوانب الطرق أثبتت عدم قدرتها على حل هذه المعضلة إما بسبب غلاء كلفتها أو عدم فاعليتها. في هذه الورقة يتم اقتراح نظام بسيط ومنخفض التكلفة للكشف عن الحيوانات على الطرق السريعة وبالتالي تفادي حدوث الاصطدام بين المركبات والحيوانات باستخدام طريقة معالجة الصور والرؤية الحاسوبية. كما يتضمن النظام طريقة لتحديد المسافة بين الحيوان والمركبة باستخدام كميرا مثبتة بالمركبة. وبشكل أكثر تحديدًا، سيتم استخدام الرسم البياني للتدرجات الموجهة (HOG) في هذا العمل كواصف ميزة لغرض اكتشاف الكائنات (الحيوانات) باستخدام محاكاة ببرنامج الماتلاب تم تدريب النظام المقترح على صور إيجابية وسلبية للإبل على الطرق السريعة بصحراء ليبيا. وللتحقق أكثر من صحة النتائج تم تجربة النظام المقترح في ظروف جوية مختلفة في الطرق الصحراوية الليبية وقد تمكن من تمييز وجود الحيوانات وبدقة عالية.

*Corresponding author:
E-mail addresses: sal.alsaid@sebhau.edu.ly, (H. AbouGrad)h.abougrad@uel.ac.uk, (A. Abubahia)a.abubahia@yorksj.ac.uk, (N. ali)naeima.ali@fit.sebhau.edu.ly
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1. Introduction

Wildlife-vehicle collisions (WVCs) are a major issue and one of the leading causes of traffic tragical accidents worldwide. Deer, moose, camels and kangaroos are few examples of wildlife that cause fatal accidents in the United States, Canada, Europe, the Middle East and Australia. Because the size of these animals is considered to be large, the accompanying collisions are often associated with high mortality rates [1]. The severe consequences of these accidents can lead to loss of human life and substantial material and moral damage. In Libya, the growing number of vehicles and the expansion of highways in natural areas have boosted the incidence of vehicle-animal collisions in desert roads. In the southern region of Libya, and the desert roads in particular, the presence of camels poses an imminent danger to travellers, because the camel is considered a large animal (the weight of an adult male reaches 700 kilograms), which makes the accidents resulting from camel collisions fatal ones [1]. The stray camels along these roads are considered as a major cause of serious accidents. Such unfortunate accidents are escalating due to the lack of intelligent safety and alert systems on highways. Road traffic accidents in Libya cause approximately 4–5 deaths each day and are the third leading cause of death; they have also resulted in a high number of disabilities [2]. All of these backgrounds have urged the need to develop advanced safety systems that are capable of saving the lives of travelers on long desert roads. Although many practical solutions exist for automatic lane and pedestrian detection [3],[4],[5], researches on automatic animal detection on highways still persist. In literature, various approaches and techniques have been proposed to deal with the issue of detection the animals on the roads. Even before the advent of deep learning many object detection techniques were introduced [6], these approaches were adopted in different systems and gave reasonable accuracies. The introduction of neural networks and deep learning armed with powerful computers and extensive data have resulted a giant leap in this area of research [7],[8],[9]. New powerful and optimal solutions of object detection were formulated using the computer vision techniques, this development have proven a considerable improvement in detection and tracking animals on roads [10],[11],[12],[13]. In this paper a computer vision technique named histogram of oriented gradients (HOG) is used to detect objects in a video or image [14]. This paper is organized as follows. In Section 2 the research objectives are defined, the utilized image processing tool is then described within HOG feature descriptor in Section 3. In Section 4 we present the distance calculation scheme which is used to convert the pixels data into distance in meters. Experimental simulations are performed in Section 5 to demonstrate the performance of the proposed detection system in real scenarios. Finally, Section 6 concludes the paper.

Fig.1: Dataset images of camels near roads taken from different angles and distances from the camera in desert roads.

2. Research Objectives

Intelligent driving assistance systems can significantly reduce accidents caused by animal-vehicle collisions. This research aims to develop a low-cost automated system for detecting animals on roads and highways, alerting drivers promptly upon detection. Specific objectives include:

a) Developing an automated system to detect animals and alert drivers.
b) Determining the approximate distance of detected animals from the vehicle's camera.

3. Image processing

Image processing involves converting an image into a digital format And performing various operations on it to enhance it or extract valuable information. This process treats the image as a form of signal input, which could be a video frame or a photograph, and produces an output that might be another image or features related to the original image. Steps in Image Processing The process of image processing includes three fundamental steps [15]:

I. Image Acquisition: Importing the image using a scanner or digital imaging device.
II. Image Analysis and Enhancement: This includes processing, improving, and analysing the image, such as compressing data and detecting patterns that are not immediately visible, like those in satellite imagery.
III. Output Generation: The final stage involves modifying the image or generating a report based on the analysis results.

3.1 HOG feature descriptor

The Histogram of Oriented Gradients (HOG) descriptor is particularly effective for detecting animals in videos or images due to several key benefits. Firstly, it processes local cells, making it resistant to geometric and optical changes. Secondly, the combination of coarse spatial sampling, fine directional sampling, and robust local optical normalization allows the system to ignore variations in animal movements as long as they remain mostly upright. The extracted features are then used for classification, enabling the detection of animals based on these features [14].

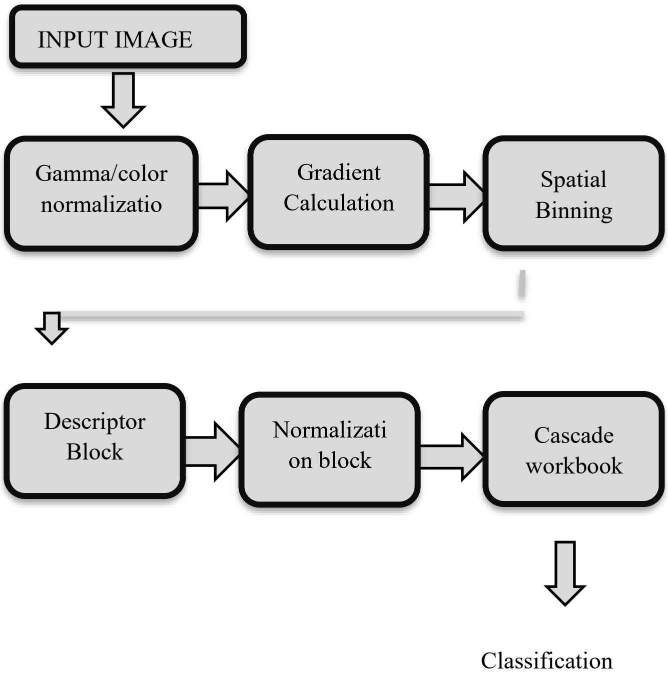
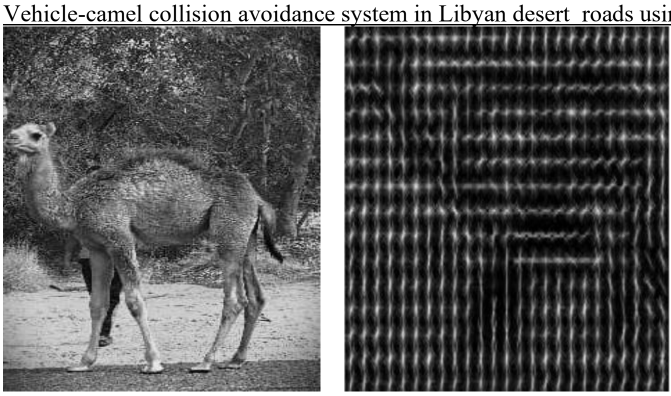


Fig.2 :HOG algorithm

Figure.3. shows an initial (original) animal image and the image after applying the HOG algorithm. It can be noted that in Figure 3.b, each "*" represents a cell with nine boxes and its size and this box is shown or given by the luminance of each direction vector.



(a) Original image (b) After applying the HOG algorithm.

Fig.3: The initial (original) image after applying the HOG algorithm to an animal image.

The HOG algorithm is convenient for detecting animals in video and images thanks to some key advantages as compared to other descriptors. First of all, it is capable of describing contour and edge, and in addition it is distinguished in various objects such as automobiles, bicycles, animals (camels), pedestrians, etc. Secondly, it works on locally on the cells and hence it is geometrically considered to be constant and thus animals can be overlooked if they maintain an almost upright position [11].

3.2 Animal database collection

These datasets incorporated images and videos captured under different weather conditions (morning, afternoon, and evening), alongside images sourced from the internet, to compile a comprehensive animal image database. Therefore, a new animal database has been established. A high-quality database is essential as it significantly influences the final outcomes [16].

3.2.1 Positive image database

To enhance classifier performance, the creation of a positive and negative sample database is crucial. Following the establishment of the image and video database, the next step involved setting up two distinct folders within the database: the Positive Exemplar Image Database folder and the Negative Exemplar Image Database folder. A Positive sample image specifically features the target animal (the camel). To achieve improved detection accuracy, animal videos and images were gathered from moving vehicles across varying weather conditions (morning, afternoon, and evening), capturing different perspectives of camels in different locations. The Positive Exemplar Image Database includes images of camels in various orientations (right-facing, left-facing, front, and rear views). Figure 4 shows some positive images of camels [16].

Fig.4: Images of a positive sample.

3.2.2 Negative image database

A negative image refers to an image where the target animal (camel) is absent. When detecting objects in environments like roadways, having a database of true negative samples (background) can significantly enhance the performance of the final detector. In scenarios requiring real-time animal (camel) detection, the background can consist of various elements such as roads, vegetation, urban areas, etc. Including these elements in negative sample images is crucial for improving the effectiveness and accuracy of target detection. Figure 5 shows some negative images [16].

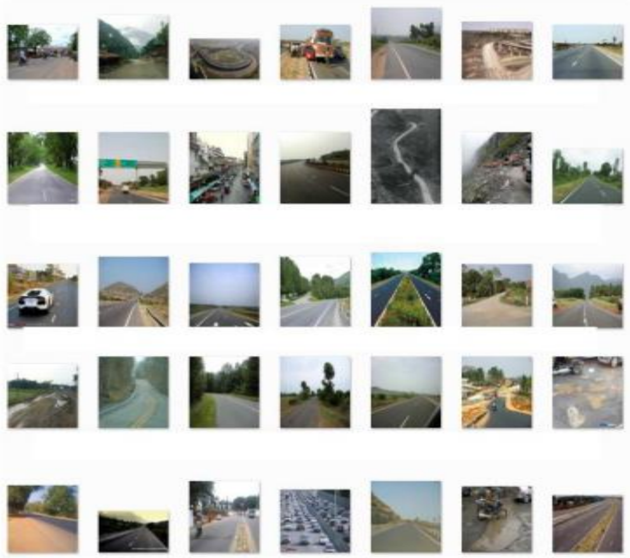


Fig.5: Images of a negative sample

4. Distance calculation:

The camel-vehicle accident can happen in different scenarios, Figure 6 shows an obvious one in which the animal confronts the vehicle. After animals are detected, a distance calculation is performed between the detected animal and the test vehicle or road. The distance value in pixels is then converted to meters. Depending on the distance of the animal from the car fixed on the camera, three types of messages (signal) are given to the driver, i.e. the animal is very close, if the animal is very close to the car, the animal is a little far away, if the animal is a little far away from the car the car is very far, If the animal is too far away and a safe distance from the car.

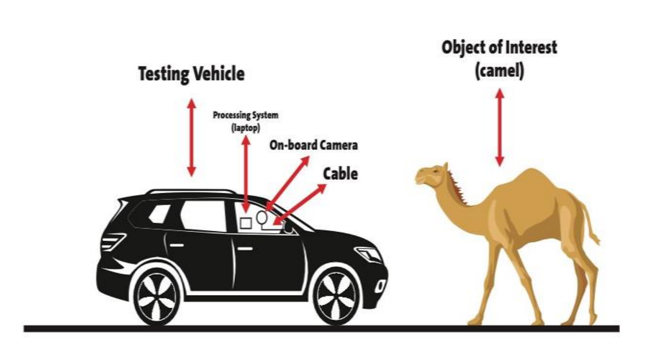


Fig.6: Explanation image for camel-car accident.

4.1 A method for approximation the distance calculation of the detected animal from the testing vehicle:

When the video (frame) detects an animal, the next step should be the distance calculation of the identified animal from the camera mounted on the vehicle so that the driver is alarmed of how far the animal is from the vehicle and if any safety measures need to be applied such as braking and/or invoking other system(s) to prevent animal-collision [11],[8].

4.2 Distance Calculation in Pixels

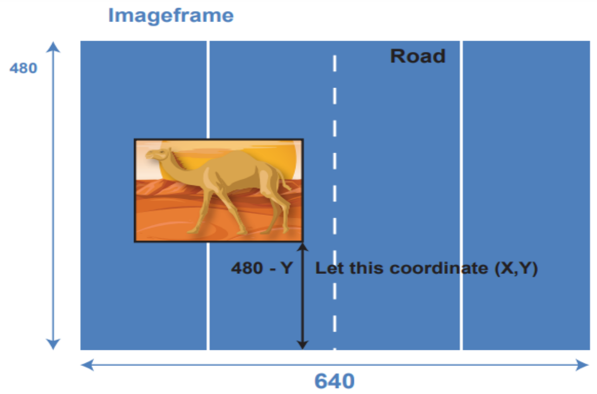


Fig.7: Distance calculation using image frame.

As illustrated in Figure.7. a video clip is captured and changed into frames (image with size 640*480).

The method for calculating the distance of the detected animal from the vehicle installed with the camera in pixels can be summarized as follows:

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

Let the bottom-right coordinates of the detected sentences be y, (x) then the distance of the sentences from the bottom edge (car/camera) is 479 – y. Note: The above method of calculating distance works well for flat terrain Surface. It suffers a little if the ground surface is not completely flat.

4.3 Distance conversion from pixels to real-world units

The relationship between the depth of the object in pixels and its true depth in distance units (meters) of the vehicle's camera can be calculated in the frame. When the depth of the object in meters is set from the camera, the composite increases (the size of the object decreases), and the depth in pixels also increases. This correlation can be used to find a relationship between the depth of an object in pixels and meters. Once the camera was placed in the car and the camera was lifted from it, the ground was stabilized (camera calibrated), and we took different pictures of the same ground. The object was kept at different depths from the centre of the camera. We then noted the corresponding depth of the object in pixels. In [11] the depth in meters versus depth in pixels is plotted in Excel and the best quadratic polynomial equation is:

$$y=0.0323x^2+22.208x+1.3132$$

Where y is the depth in pixels and x is the depth in meters [8].

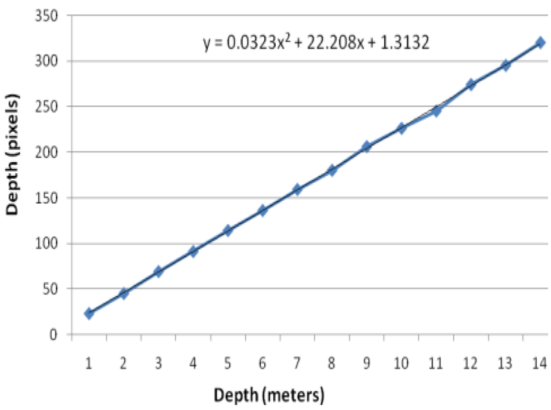


Fig.8: Graph of depth (meters) versus depth (pixels) [11]

5. Results

In this section, the proposed system is tested using real scenarios in which a simulation camera set up collects snapshots for the animal while crossing the roads in the vicinity of Sebha city in Libya. These photos are then processed using the HOG computer vision system, and the results are finally displayed to the driver. Two experiments were carried out, the first was accomplished during the day time whereas the other was performed at night. The following subsections demonstrate the outcomes for both of the experiments.

5.1 Experiment 1 – During the day

Figure. 9, shows the detection of the animals in a clear view weather during the day, whereas, Figure .10 illustrates the multiple stages of the image processing for the detected image. These stages have shown that the utilized HOG algorithm was able to distinguish the targeted object (the camel) smoothly in the clear weather condition. The results of the accuracy and distance are shown in Table 1.

Fig.9: Camel captured in the morning – good weather conditions.

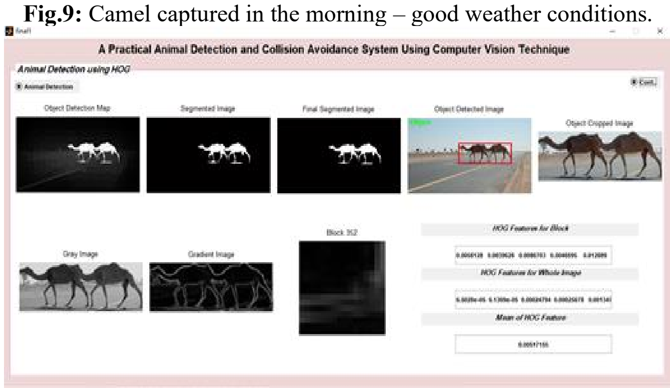


Fig.10: The processing of a camel image in the day time.

Table 1. Distance calculations and accuracy for experiment 1.

Distance in pixels	Distance in meters	Accuracy%
140.175	6	80

5.2 Experiment 2- At night time

Figure. 11, shows the first detection of the animals in night time. On the other hand, Figure .12, shows the multiple stages of the algorithm image processing for the snapshot that was taken by the camera. These stages have shown that the utilized HOG algorithm was able to distinguish the targeted object (the camel) with some difficulty in the windy weather condition. The results of the distance calculations as well as the accuracy are shown in Table 2.

Fig .11: Camel captured in the night - windy weather.

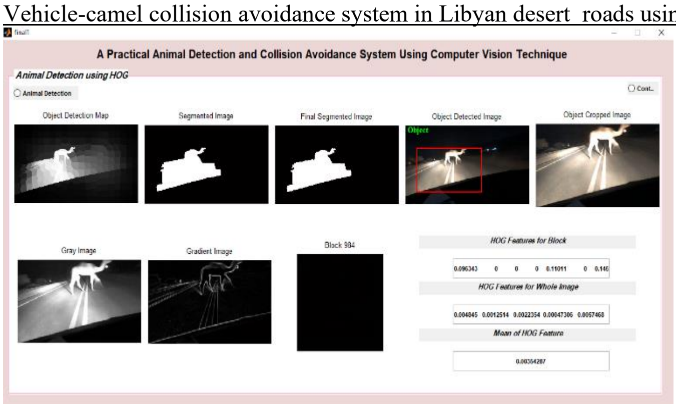


Fig .12: The processing of a camel image in the night time.

Table 2. Distance calculation and accuracy for experiment 2.

Distance in pixels	Distance in meters	Accuracy%
109.142	5	80

6. Conclusion

In this paper an automated detection method using computer vision technology was proposed in order to reduce the number of collisions that occur due stray animals. The animal detection on desert roads of southern Libya was addressed using a system based on HOG optimization and cascade classifier enhancement. The experimental results have demonstrated that the algorithm was able to detect the animal (camel) in different weather conditions and during both of the day and the night with high accuracy in both of day time and night time experiments. In the interest of achieving a reliable algorithm the distance information was also obtained using pixels to distance conversion scheme. By taking some considerations, the proposed method could be extended to detect other animals than the camels in variant climate conditions.

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