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Characterization of Honey Bee Anatomy for Recognition and Analysis Using Image Regions

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Abstract. Extraction of object features in an image, for automatic recognition, is one of the main parts of a computer vision project. Extracting features of the objects in an image from a real environment, without controlling factors that influence the acquisition of the image, has a high degree of complexity. This paper describes a method to characterize the anatomy of honey bees, with images acquired at the entrance of the hive in an apiary using digital image processing and automatic classification methods for recognition and analysis. The method was tested with a base of 1050 real test images divided into incremental subsets of 50 images. Recognition was performed with the Support Vector Machine (SVM) and k-Nearest Neighbors (kNN). Two performance parameters were evaluated, the percentage of correctly classified images with the presence of the bee in the entrance of the hive and the classification time for each evaluated subset. The results of the experiments show better recognition percentages with the SVM while the recognition times of the image subsets using the kNN method are better.

Keywords: Apiary, honey bee, automatic recognition, support vector machine, k-nearest neighbors.

1 Introduction

Object detection is a fundamental visual recognition problem in computer vision [18]. When this problem is addressed with image objects in an environment of controlled factors and in a specific position, the implementation of the techniques to recognize the objects is not complex. On the other hand, when this problem is addressed with the recognition of objects contained in images of a real environment and in different positions of the object, the degree of complexity when implementing techniques for feature extraction and recognition increases.

In a real environment, different factors influence the images that are acquired. The first factor to consider is the lighting that is related to the environmental conditions, i.e., if the images are acquired during the day or at night, on a cloudy day, with rain, with a lot of wind or with full sun, the lighting affects the surface and the objects to be analyzed.

A second factor is the area of the real environment from which the images are extracted for the analysis of the objects; it must be considered if the objects are in movement or they are static. Consider whether the objects being analyzed are inanimate or living beings; inanimate objects in motion are generally moved by a device to regulate their speed; in case of living beings, the complexity is greater, since the movement is unpredictable, their positions cannot be controlled.

Then, when the objects present movement and different positions in the image, more distortions must be treated in the processing with more complexity and higher processing speeds [18]. Due to the above, it is necessary to apply digital image processing techniques and object recognition in the image with different strategies for detection and recognition objects in the scene; many strategies have been proposed in the literature.

This research work deals with the recognition of objects in different environmental conditions, in a real environment and with living beings. The strategy of using regions of interest in the image has been chosen [18, 17] a technique similar to two techniques called block-oriented image decomposition structures [11] and the technique based on the subdivision of the image matrix into four quadrants of equal size [4].

With the above described, this paper presents and describes an investigation for the automatic recognition of bees in the entrance of the hive. The recognition is made from images taken from an apiary with live bees that have different positions. This research is the continuation of the work presented in [15], and its main objective is to develop a method with the three most common phases of automatic shape recognition, namely, digital image processing, the extraction of the characteristics (namely, characterization) of objects in the images and the recognition of the object in the image.

Digital image processing is carried out with different techniques as explained in the following sections; extraction of characteristics of objects is made using the coloring method [13, 1] and the Freeman Chain Code method [14, 5, 2, 8] for the generation of feature vectors [11, 2, 8]; and the recognition of the object in the image is carried out with the Support Vector Machine (SVM) and k-nearest neighbors (kNN) [17, 3] methods. Each of the three phases that constitute this research project is explained in the following sections of this work together with the techniques used in each phase.

In this work we use the terms honey bee and object of the image interchangeably to refer to the presence of the honey bee at the entrance of the hive. In section 2, some works related to this research are described. Section 3, problem statement, describes the general environment of this research. The basic concepts used are described in section 4, for a better understanding of the problem. Section 5 phases of the project, explains the way in which each of the three phases that constitute the proposed method was implemented; Section 6 presents the results obtained with the experiments carried out. Finally, section 7 presents the conclusions of this research project.

2 Related Works

Due to the fact that this research has several research areas, due to space issues, only a very small number of works related to the recognition of objects by identifying the regions of the images are commented in this section.

The concept of regions in image processing has been extensively studied in different research papers [17, 4, 13, 1]. The seminal work described in [4] makes use of quadtrees to represent image regions and obtain a simple type of boundary representation.

In [1, 9], the use of a reduced number of labels, which does not exceed a certain amount, is proposed for the identification of the regions, and ensure that two neighboring regions with the same label cannot exist; information about some region pixel is added to the description so that this can provide a complete region reference.

All information is stored in a separate data structure. A widely used algorithm is proposed in [12], and applies to images encoded by sequence length and on images represented as straightforward matrices. Other technique, proposes a model to address the classification problem by detecting if a region contains both "background" and "foreground" regions [17].

Moreover, in [11] a block-oriented image decomposition structure can be used to represent image content in image database system. In [1] image regions are used to classify only a specific region of the image that corresponds to a given object using Convolutional Neural Nets (CNN). Considering the works described in this section, in this research the regions of the images are used as areas of interest to extract characteristics of the object and allow the recognition of the object in the image.

3 Problem Statement

Application of technologies for the care and preservation of species in the world is necessary. Sometimes, actions of human carry out to stop the disappearance and loss of animal species are not enough, therefore, technological developments are needed to help in the early detection of diseases or parasite attacks on species.

This research work has been divided into three stages. The first stage was published in [15], the second stage is presented in this paper, and the third stage is currently being worked on.

So, this second phase of the research project focuses on the detection of the presence of bees at the entrance of the hive with the use of images of the real environments in the apiaries, which will lead us in a future work to the detection of ectoparasites in honey bees. Some reasons why this research is justified are the following:

– Develops an automated system for the detection of bees in the entrances of the hives, using as a base the communication platform installed between an apiary and a cluster of servers [15].

– Explore the research area of object recognition in real settings, with living beings, using the technique of detecting objects in image regions.

– This work will serve as the basis for the current development of an automated visual inspection system in real time, to detect ectoparasites in honey bees and contribute to the care and preservation of honey bees in the "Region del Llano", which is located between the states of Jalisco and Aguascalientes, Mexico. In this region, honey bee is cultivated for honey production and also as a pollinator of crops.

4 Basic Concepts

For a better understanding of this research, this section defines a set of terms that will be used in the following sections:

– Image. An image is a spatial representation of an object, a two-dimensional or three-dimensional scene [6]; this can be modeled by a continuous function of two variables $f(x,\ y)$ where $(x,\ y)$ are coordinates in a plane [13].

– Region. A region is a connected subset of a $2^n - by - 2n$ array, which is made up of unit-square "pixels" [4].

– Segmented Image. From [13] we obtain that a segmented image R consists of m distinct, disjoint regions R_i, as clearly shown in equation 1. The image R consists of objects and a background:

$$R_b^c = \bigcup_{I=1, i\neq b}^{m} R_i, \tag{1}$$

where R^c is fixed complement, R_b is considered background, and other regions are considered objects.

5 Project Phases

This section describes the way in which each of the three phases of the research project was implemented. Digital image processing phase shows the techniques applied in each step of image processing; the characterization phase of the regions in the image, mentions the algorithms applied to label each region of the image, the features calculated for each region, and the way in which the feature vectors are built; finally, the recognition of the object in the image, mentions the two techniques applied to recognize the presence or absence of the honey bee in the image; for better under- standing of the reader, the techniques applied in each phase are mentioned.

5.1 Digital Image Processing

In this phase, the digital treatment of the images extracted from the apiary is used; the processes applied are image cropping [19], the conversion from a RGB (Red, Green and Blue) image to gray [12], Gaussian blur, The Canny edge detector [14, 10] and contour detection [14].

For the example of the digital treatment of the image, consider image 1, this image (like all the images that are processed) is extracted from the apiary, and acquired in the entrance of the hive [15]; a white background is adequate on the surface of the entrance to highlight the presence of bees; figure 1 shows the presence of 6 live bees; 4 bees are considered as complete objects, and 2 bees segmented by the acquisition equipment; of the two segmented bees, one bee shows only the abdomen and the head of the second bee appears with a frontal shot in the image.

Fig. 1. An image taken from the apiary and acquired in the entrance of the beehive.

Please let me comment, this image has been selected from set of images, because it is suitable to explain each step of the digital treatment of images. Each row of image 2 shows the results of applying the 4 processes to the original image 1. In the following sections, each of the processes is explained in a reduced way, due to space issues:

– **Image cropping:** Due to the actual size of the extracted image, a cropping process [19] is necessary. This process allows to divide the image and obtain three smaller images that allow to improve the processing. The three images in row 2b represent the image after the cropping process.

– **Conversion from RGB image to gray:** The process of converting the image from RGB to grayscale is to simplify the algorithms and also remove complexities related to computational requirements. Image 2c shows each image after the RGB image to gray conversion process.

– **Gaussian Blur:** A necessary function to eliminate mute noise is necessary after the conversion to grayscale. Then a Gaussian blur for noise is applied. The image 2d shows each image after the process of making the conversion to Gaussian blur.

– **Canny edge detector:** An Operator for edge detection is applied after Gaussian blur. The Canny edge detector [14, 10] was selected, like a multi-stage algorithm to detect the wide range of edges in the image. Image 2e shows each image after the process of applying the Canny edge detector.

– **Contour detection:** Contours detection is an important image processing technique [14], and is a process for curve joining all the continuous points (along with the boundary), having same color or intensity. In this research work we are evaluating the application of some techniques proposed in the literature. Obtained results are explained in the next sections.

5.2 Characterization of Regions in the Image

After the digital process of image, identification of regions in the image is started. The identification of regions in the image is the most important process in this work, because the identification of object shape allows us the complete recognition of the bee.

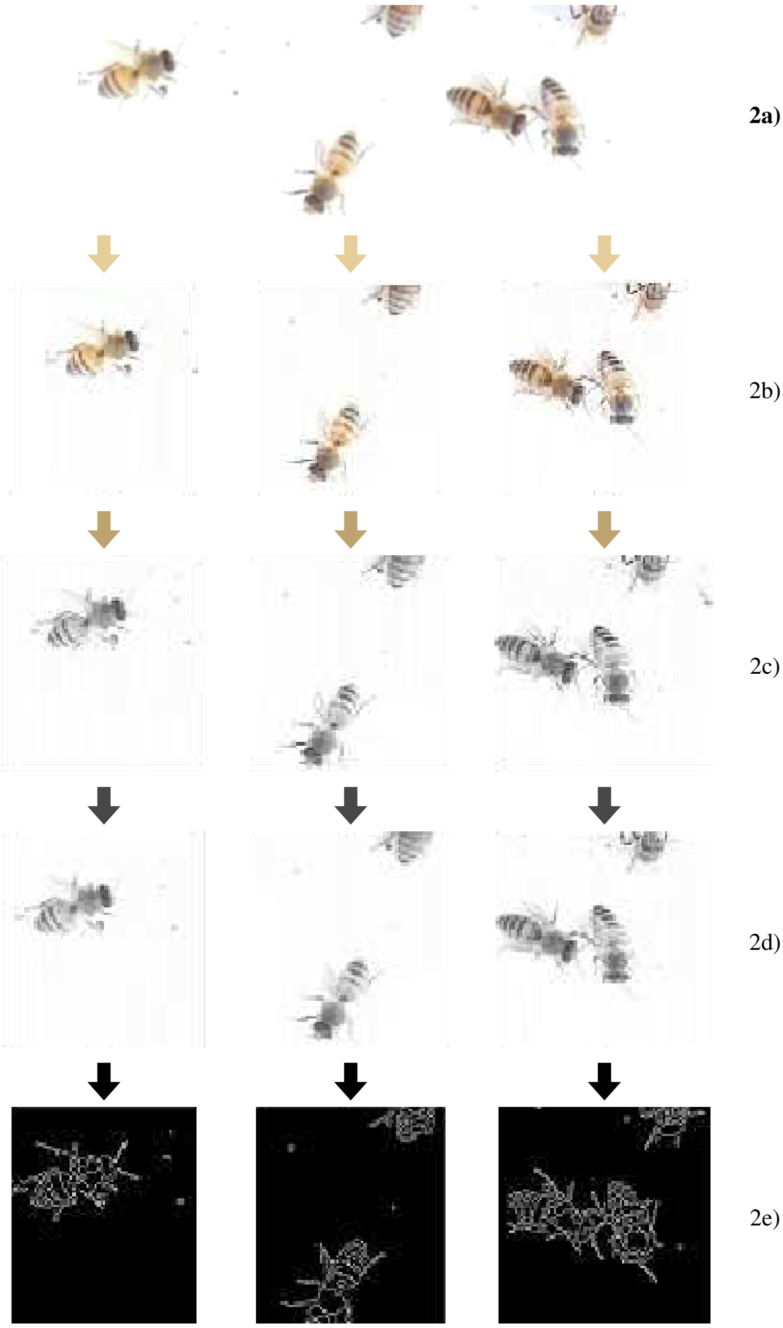
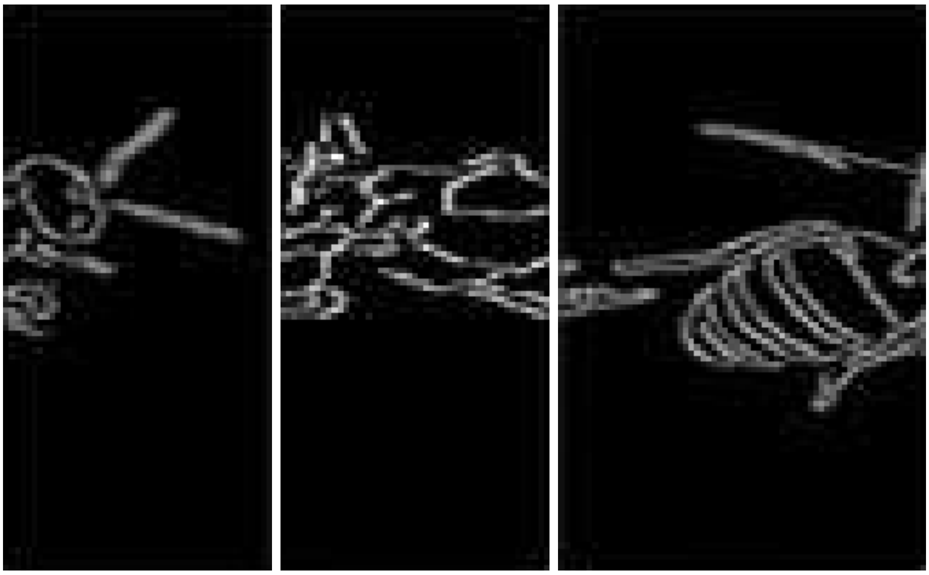


Fig. 2. Original image to which each of the phases of digital image processing is applied. The Image in row 1a is the original image, the images in rows 1b, 1c, 1d and 1e show the original image after the cropping, RGB image to gray, Gaussian Blur and Canny Edge detector processes respectively.



(a) (b) (c)

Fig. 3. Segmentation of the image of the hive into its constituent parts, for the detection of regions; a) head and antenna, b) thorax, c) abdomen and hind legs.

This identification is carried out by segmenting the images into different semantically significant regions [12, 16], to detect the objects and edges in the image [7]. Given the above conditions, to recognize the parts of the bee, this paper proposes the method of labeling or coloring (also called, connected component labeling) [13, 1, 12], to label each region with a unique integer.

In this work, the input to the labeling algorithm are binary images (with images produced after contour detection), where the background is represented by pixels with zero value and the objects by non-zero-pixel values. The result after labeling is an image with the background represented with zero values and the regions represented with non-zero labels. Each region is characterized and this information is stored in a separate data structure called the feature vectors [11] of the regions.

In the next phase for the recognition of the object in the image, mathematical morphology approaches are used for region identification. In the following paragraphs, the way in which the isolation of the regions in the image is carried out and the generation of the feature vectors [11, 8, 9] of each region found is explained, as well as the discrimination noise in the image for object identification.

Please consider that the images obtained with the contour detection algorithm (the three images in row 2e of image 2) are not cropped; for explanation purposes 1 of row 2e is cropped as shown in image 3.

Consider images come from a real environment, this causes the definition of the contours in the last phase of the image processing (consider the first image of the row 2e) of image 2), are not defined correctly and the shape of the bee is not complete for recognition. Image 3, shows the first image of row 2e of figure 2 in a cropped form.

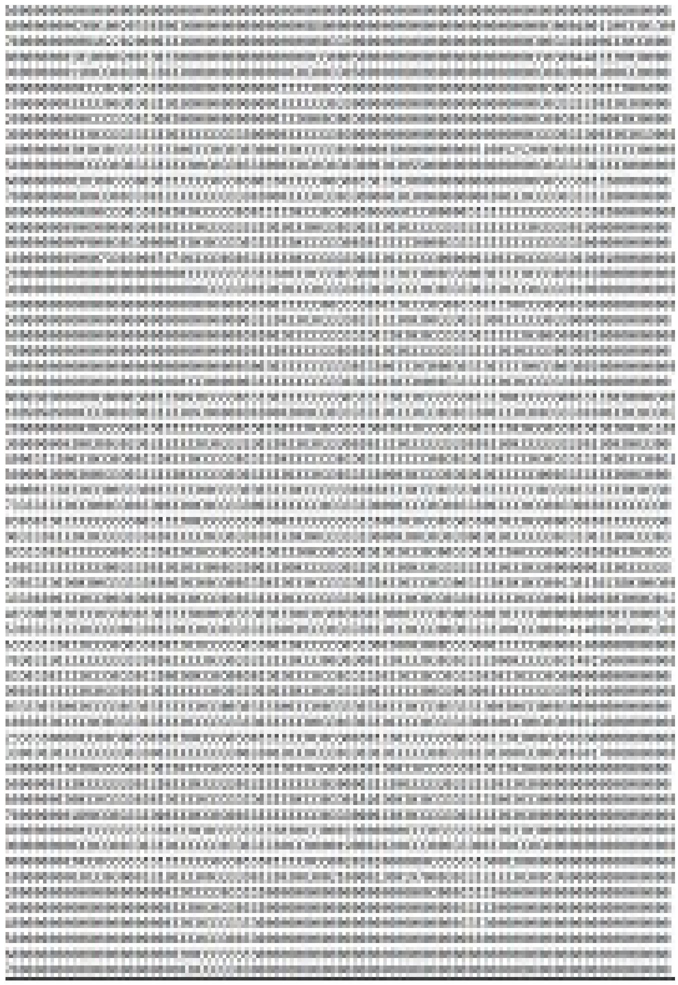


Fig. 4. Result of applying the coloring algorithm to the first image of row 2e of image 2.

The division into different semantically significant regions lead the example presented here; it is clear that the contours of the head and the antennae of the bee are defined, but not united, which produces that the shape of this part of the bee is partially complete, see image 3a. One way to deal with the problem of incomplete contours or noisy contours is to apply thinning techniques to the image, but in our case, these techniques were not suitable for the expected results.

For the next two parts of the bee, the thorax and the abdomen, Figures 3b and 3c respectively, the contours are not joined; these contours are segmented into several parts and incomplete, even the curvilinear shape of the thorax is not shown with contours. Despite this, some parts of the bee can be recognized, for example, the abdomen and hind legs can be recognized if the algorithm is able to solve the segment joining problem.

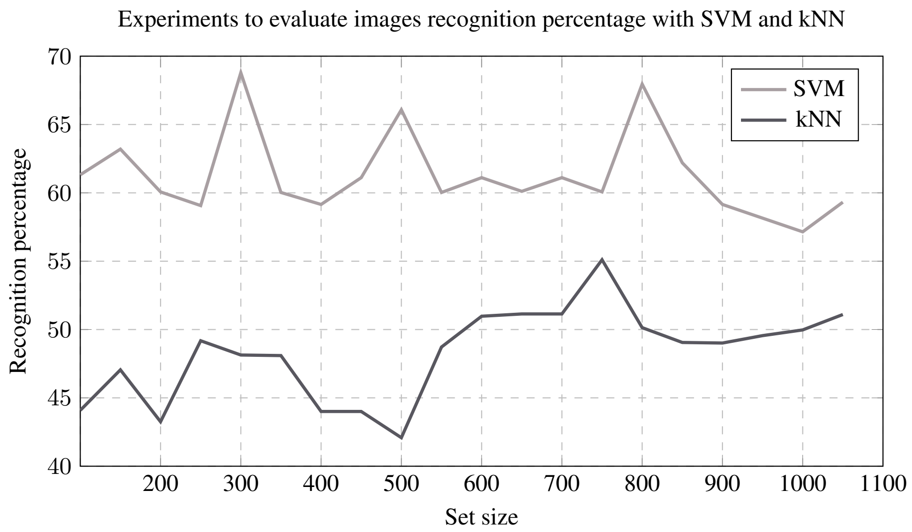


Fig. 5. Recognition percentages for each set of test images, applying SVM and kNN techniques.

When encountering this problem, the strategy used in this work is to identify the non-joined contours through the regions; and then characterize each region to finally perform a calculation of closeness between regions. If the regions identified as antennae are close to a region identified as the head, then we are identifying the frontal part of the bee. Obviously, the classifiers used previously "know" the regions of the bee.

Considering the segmented contours in the image, the coloring algorithm was used directly after edge detector process. In the next section the process of applying the Coloring algorithm, Freeman Chain Code algorithm and discrimination of noise in the image are explained.

Application of the Coloring algorithm. The result of applying the coloring algorithm [13, 1], can be seen in image 4. Each of the regions are segmented with identifiers after the execution of the algorithm. We can observe the following: Near regions can have near region numbers. That is, if we consider an antenna of the bee, it will have a number of close regions of the head or of the other antenna, which allows us to apply the Manhattan algorithm to find the closeness of regions.

Application of the Freeman Chain Code algorithm. This algorithm string records the movement of tracker during complete tracing of character structure, from which shape primitives, consists of simple line and curve shapes [8]. Once the regions have been identified in the image, the Freeman Chain Code algorithm [14] is executed to identify the features of each region.

This algorithm again scans the image for the extraction of the features of each region. The first characteristics calculated for each region are: the perimeter, the density and the area, which are stored in the vector of characteristics of the region in question. In a second cycle, the algorithm computes the corners, concavities, and moments of each region; in the same way the results of the calculations are stored in the feature vectors.

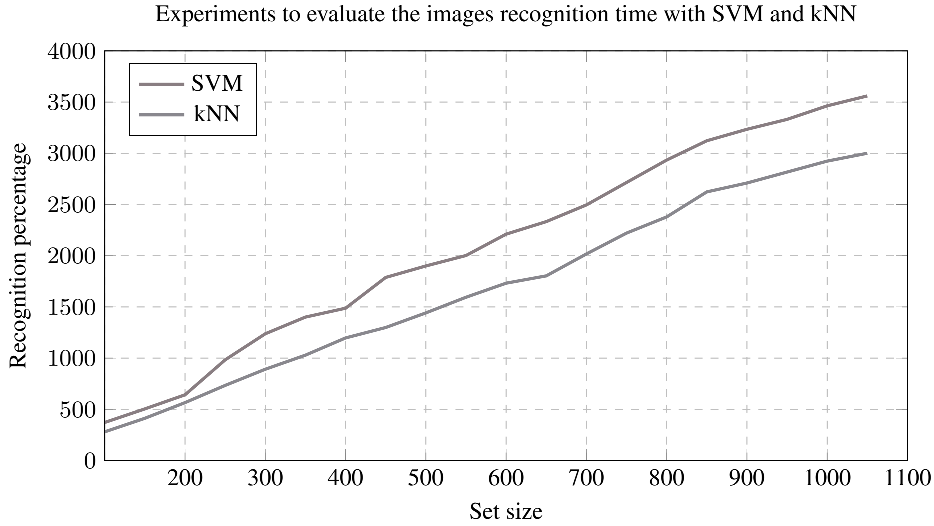


Fig. 6. Image processing time, applying SVM and kNN techniques.

Noise discrimination in the image. The noise in an image are regions or parts of the image that must be discriminated to achieve a better recognition of the object. Removing noise from the image is a process that is difficult to develop, but necessary because if it is not eliminated, the object is not recognized, it is partially recognized, or it causes confusion of the object with parts of the image that do not correspond to the object. In this work, the noise discrimination or elimination process occurs when the characteristics of the regions not recognized as part of the bee are extracted, and do not match with any of the parts of the bee.

Otherwise, if the algorithm indicates, this region is coincident with some part of the bee, other parts of the bee must be close or close in the neighborhood of regions. To calculate the closeness between regions, the distance from Manhattan is used. As a condition to enforce the member- ship of a region to the bee, it must be true that a region has a distance from Manhattan relative to at least 3 neighboring regions. Obviously, it is a condition that is not verified for the first three regions found in the image.

5.3 Recognition of the Object in the Image

In a summary form due to space, this section explains the third phase, which is the recognition of the object in the image using the SVM and kNN methods. This phase of the project proceeds as follows, the generated feature vectors serve as input to the two methods to allow the identification of each of the parts of the honey bee such as antennae, head, thorax, abdomen and limbs (paws).

By joining the recognitions of each part of the bee represented by the feature vectors, it is determined whether the object in the image is the honey bee or not the honey bee in the image. The lack of feature vectors of some parts of the bee is decisive to discriminate the image and determine if the object (honey bee) does not exist.

6 Experiments

For the experiments explained here, a base of 1050 images were processed without discrimination, i.e., the images were acquired over a period of one month, once the remote image acquisition system of the apiary was put into operation. To carry out the experiments, the image base was divided into incremental groups of 50 images. Two parameters were evaluated, the recognition percentage and the image processing time. The recognition percentage allows knowing the number of images that were recognized in each group of images that is evaluated. This parameter also makes it possible to compare the results of the two recognition techniques and observe the effectiveness of each technique.

The processing time is important because one of the objectives of this research project is the processing of images in real time for the detection of ectoparasites in bees, so to determine which recognition technique is the fastest, this parameter was evaluated. Another important aspect to consider in the experiments was the position of the bees without rotation, i.e. the bees in the image are considered in the same position because in this investigation, the environmental conditions (illumination) that pre-vailed during the acquisition of the images in the apiary, were considered.

Also, in these experiments the six calculated characteristics were considered. In future work, we consider dividing the features into two subsets of three features each, with the aim of improving processing times and observing the incidence of each feature on object recognition. With the above described, the results obtained so far with each parameter evaluated are described in the following paragraphs.

6.1 Recognition Percentage

This experimentation was carried out to know the effectiveness of the SVM and kNN techniques together with the generated feature vectors. Graph 5 shows the recognition percentages for each set of test images. The graph shows the effectiveness of the SVM technique; it provides better results as a recognition technique using feature vectors. As it is possible to observe, as the number of images increases, the recognition percentage does not decrease compared to the kNN technique.

Here, we consider the number of images recognized by SVM can help the results in a real recognition environment. The kNN technique is optimal for smaller image sets, but as the number of images increases, classification is complicated. Although the recognition rates increase when the number of images in the set is 500 or more, it is not enough to outperform SVM.

6.2 Image Processing Time

Graph 6 shows the times obtained in the experiments with different sets of processed images. kNN stands out as a technique with shorter recognition time, when classify- ing the objects in the images; kNN is a technique with a very fast recognition convergence, which allowed to classify the images of each subset in less time compared to SVM; according to the increase of images in the sets of processed images, the response time of the classifier remains stable and is robust; although it should be noted, evaluation tends to generate more false positives than the SVM classifier. SVM shows itself in the experiments as a more stable classifier with longer time, but with fewer false positives, i.e. it is more accurate in the classification.

7 Conclusions

This work describes a computer vision system, whose mission is to identify the presence or absence of bees in the entrance of the hive. The system performs in a real apiary environment and considers the most important factors affecting image acquisition. The way to achieve the classification is through the application of digital image processing techniques and techniques for the recognition of the object in the scene.

Two common classifiers in the literature were evaluated, with 2 performance parameters, the recognition percentage and the recognition time of the objects in the image with two supervised classifiers, kNN and SVM. The results obtained in experiments show SVM as a classifier with better responses, although more time consuming. kNN has better response times but with more errors when classifying the objects. These results are being considered in the next phase of this project.

Also, this work demonstrates the feasibility of using new technologies for the care and preservation of species. This work is constituted as a part of an integrative project whose final objective is the detection of ectoparasites in bees in real time. The final phase is currently being developed, which integrates the project proposed in [15], and this research work.

8 Future Works

Future research work is to develop the subsequent analysis of each of the parts of the honey bee, to detect the presence of attacks by ectoparasites and help the conservation and care of this species.

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