UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Image Processing Algorithm for Improving the Identification of Patterns in Mosquitoes Wings

Artículo Académico

Rocío Alejandra Guerrón Torres

Ingeniería Electrónica

Trabajo de titulación presentado como requisito
para la obtención del título de
Ingeniera Electrónica

Quito, 13 de mayo de 2016

UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

COLEGIO DE CIENCIA E INGENIERIAS

HOJA DE CALIFICACIÓN
DE TRABAJO DE TITULACIÓN

Image Processing Algorithm for Improving the Identification of Patterns in Mosquitoes Wings

Rocío Alejandra Guerrón Torres

Calificación:

Nombre del profesor, Título académico Diego Benítez , Ph.D.

Firma del profesor ______________________

Quito, 13 de mayo de 2016

Derechos de Autor

Por medio del presente documento certifico que he leído todas las Políticas y Manuales de la Universidad San Francisco de Quito USFQ, incluyendo la Política de Propiedad Intelectual USFQ, y estoy de acuerdo con su contenido, por lo que los derechos de propiedad intelectual del presente trabajo quedan sujetos a lo dispuesto en esas Políticas.

Asimismo, autorizo a la USFQ para que realice la digitalización y publicación de este trabajo en el repositorio virtual, de conformidad a lo dispuesto en el Art. 144 de la Ley Orgánica de Educación Superior.

Firma del estudiante: _______________________________________

Nombres y apellidos: Rocío Alejandra Guerrón Torres

Código: 00107592

Cédula de Identidad: 1715952402

Lugar y fecha: Quito, mayo de 2016

RESUMEN

En la presente investigación se desarrolló un algoritmo implementando procesamiento de imágenes para resaltar características importantes en las alas de mosquitos; siendo un proceso previo al desarrollo de una herramienta de análisis automatizado para la detección y clasificación de mosquitos basado en la morfología de sus alas. El presente algoritmo incluye: identificación de patrones, puntos de referencia y celdas a través de filtros, detectores de bordes y geometrías circulares, así como sus centros y radios correspondientes. El objetivo fue el mejorar la identificación manual de mosquitos, destacando las características más relevantes de las alas, para usar como una herramienta de entrenamiento para usuarios sin experiencia en área biológicas de interés.

Palabras clave: análisis morfológico alas, insectos, patrones, bordes, celdas, esqueleto, centros, radios

ABSTRACT

This paper presents an image processing algorithm for highlighting important features of mosquitoes' wings as a first step towards the development of an automated analysis tool for detection and classification of mosquitoes based on their wings morphology. The present algorithm includes: pattern, landmarks and cells identification through filters, edge and round geometries detectors as well as their respective centers and radii. The aim was to improve manual mosquitoes identification by standing out the most important features of the wings to be used as a training tool for non experience users

Key words: morphological wings analysis, insects, patterns, edges, cells, skeleton, centers, radii.

Image Processing Algorithm for Improving the Identification of Patterns in Mosquitoes Wings

Alejandra Guerrón and Diego S. Benítez
Universidad San Francisco de Quito USFQ
Colegio de Ciencias e Ingenierías ”El Politécnico”
Campus Cumbayá, Casilla Postal 17-1200-841
Quito-Ecuador
alejandraguerron@gmail.com, dbenitez@usfq.edu.ec
Sonia Zapata
Universidad San Francisco de Quito USFQ
Colegio de Ciencias Biológicas y Ambientales ”COCIBA”
Campus Cumbayá, Casilla Postal 17-1200-841
Quito-Ecuador
szapata@usfq.edu.ec

***Abstract*—This paper presents an image processing algorithm for highlighting important features of mosquitoes' wings as a first step towards the development of an automated analysis tool for detection and classification of mosquitoes based on their wings morphology. The present algorithm includes: pattern, landmarks and cells identification through filters, edge and round geometries detectors as well as their respective centers and radii. The aim was to improve manual mosquitoes identification by standing out the most important features of the wings to be used as a training tool for non experience users.**

***Index Terms*—morphological wings analysis, insects, patterns, edges, cells, skeleton, centers, radii**

I. Introduction

Culicoides midges inhabit world wide, mosquitoes bites often cause only some allergic reactions. [1] However, some of them are blood feeding and may transmit diseases and infections not only on humans but also on animals. In Central Africa, and in some regions of Central and South America, specially on tropical areas, biting midges cause itching dermatitis which could end on skin lesions. [2]. In animals, these mosquitoes can transmit Bluetongue viruses which affect cattle and sheeps, African Horsesickness virus that affects equines and may produce their death, and directly influence on economic losses. [1]. Therefore, fast identification of different species of these midges, could allow to localize important specific areas where they inhabit to improve their reduction and therefore avoid and prevent propagation of diseases on humans and animals. Geometric Morphometrics is the common analysis used to identify mosquitoes and also other insects. It is based on a morphological shape analysis given by geometric landmarks marked on specific parts of the animal's body. [16] The process includes manual detection of each landmark. Once the first step is done, the process may be repeated several times by the same user to gain consistency. Finally, the recollected information is statistically processed. Then, Geometric Morphometrics depends on user experience and ability, obtaining resulting with some level of subjectivity. Therefore, this research proposes a different view from traditional, to identify mosquitoes.

Fig. 1. Culicoide midge [1]

Wings on figure 2 correspond to Culicoides mosquitoes family. Note that there are several landmarks on the wing that can be used to identify the species.

Fig. 2. Original Wing's Image

II. Image Processing Algorithm

The proposed image processing algorithm implemented in this research is given by the following schema.

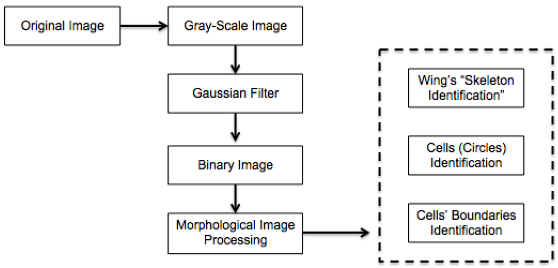


Fig. 3. Method's Scheme

The first step consists on converting the image to Gray-Scale. This purpose implies removing the hue and saturation keeping only the luminance of the corresponding image. Then, the Gray-Scale Image is obtained by applying equation 1 which is the Luminance equation

$$GrayScaleImage = 0.299 * R + 0.587G + 0.114 * B \quad (1)$$

where R, G and B are the components for Red, Green and Blue colors respectively on the original image. The weights for each color components, represent the humans eyes' sensibility to the frequencies of the spectrum that are near to RGB colors. [3].This procedure was required in order to later obtain a global threshold for the image and use it on the conversion to a binary image. The threshold was computed, based on Otsu's method. [17] Threshold is a normalized value between (0, 1). This value is obtained by calculating the probability of occurrence of each gray level, classifying pixels in two groups and calculating probabilistic measurements. [17] The resulting image is shown on figure 4

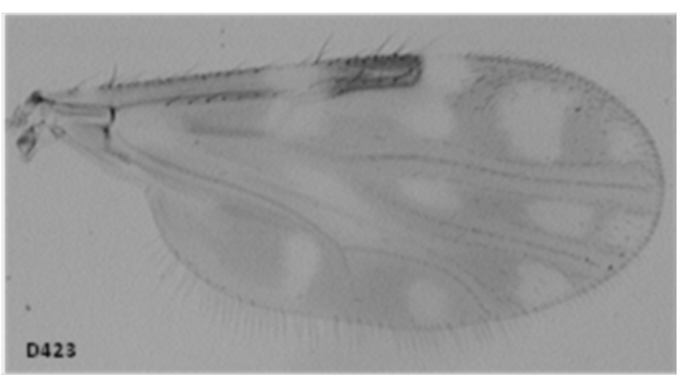


Fig. 4. Gray scale Image

Then a Gaussian Filter is used to remove noise and also to smooth the image. This is a low-pass filter, which has rotational symmetry that produces the same effect on all directions of the image's matrix [7]. When working with images it is necessary to use the two dimensional Gaussian function, described below in 2.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (2)$$

Where:
σ is the standard deviation.
x, y are the 2-D image pixels.
The implemented filter was of size 3 and $\sigma = 0.5$. The level of filtering is given by σ. The resulting image is shown on figure 5

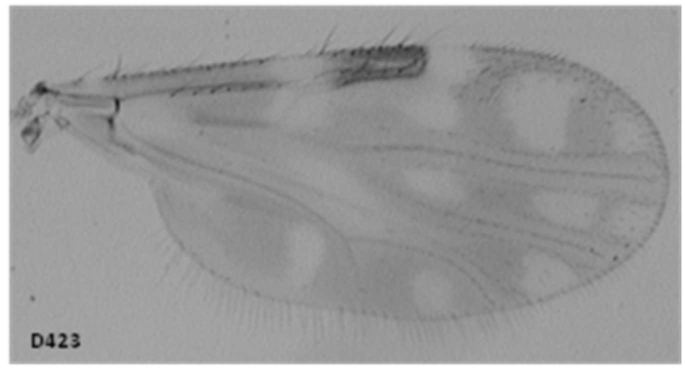


Fig. 5. Gray-Scale Image processed with Gaussian Filter

The resulting binary image contains only zeros and ones as pixels; this information is very useful on image processing since it provides efficient and important image information [10]. Once the threshold was obtained, the image was converted to binary. The resulting image was obtained by a logic process where 1's, representing white color, for every pixel that had a luminance greater than the threshold on the gray-scale image, and 0's or black for pixels that were under the threshold [9]. The resulting image is shown on figure 6

Fig. 6. Binary Image

On Figure 6, some useless pixels information still appeared, therefore it was necessary to apply other imaging processing techniques such as dilation and erosion. Both techniques are useful and important tools basically on morphological image processing. They allow to maintain principal object's characteristics as well as reconstruct shapes that are distorted and with noise. [18] Both interact with structuring elements, which basically are the mask that indicate the neighborhood structures [11]. Dilation is given by the following set operations:

$$A \oplus B = \left\{ z | (\widehat{B})_z \cap A \neq \emptyset \right\} \quad (3)$$

Where:
B is an structuring element.

$\emptyset$ is an empty set.
Equation 3 refers to the dilation of A by B, which produces a set of structuring elements at the origin locations where B, first reflected and translated, is overlapping minimum a portion of A [8]. This operation is shown on figure 7.

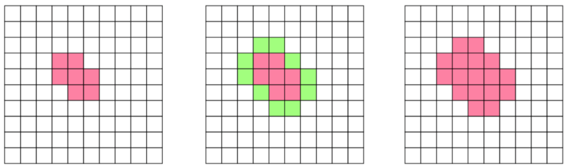


Fig. 7. Dilation

On the other side, erosion is defined by equation 4.

$$A \ominus B = \left\{ z | (B)_z \cap A^C \neq \emptyset \right\} \tag{4}$$

Where:
B is an structuring element.
$\emptyset$ is an empty set.
Equation 4 refers to the erosion of A by B, which produces a set of structuring element at the origin locations where B, first translated, does not overlap the background of A [8]. This operation is shown on figure 8.

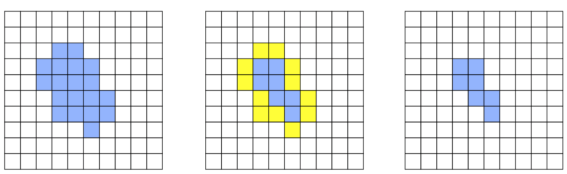


Fig. 8. Erosion

Erosion was implemented with a flat disk as structuring element, of radius 3 and with $N = 4$, which corresponds to the neighborhood. Some functions are a combination of dilation and erosion. Opening is also a morphological operation defined by equation 5. The opening of A by the structuring element B, is the erosion of A by B, with the dilation of the corresponding result by the same structuring element [8].

$$A \circ B = (A \ominus B) \oplus B \tag{5}$$

Opening is used to remove regions from objects, which do not contain the structuring elements, it can also smooth object edges. [8] Opening was used to remove small objects, with fewer pixels than an N given number from a binary image.
Closing operation is given by relation 6. The closing of A by the structuring element B, is the dilation of A by B, with the erosion of the corresponding result by the same structuring element [8].

$$A \cdot B = (A \oplus B) \ominus B \tag{6}$$

Closing was used with a flat disk of radius 1, as an structuring element.
The most outstanding features when working with these specific wings are the edges and the contours that surround the cells, then, to improve its identification, it was necessary to "thicken objects by adding pixels" [9] and also fill borders by setting a pixel to 1 if more than five pixels in its neighborhood were also 1, the neighborhood considered had size $3 - by - 3$ pixels. [9]. After all the mentioned processes were applied the resulting image is shown on figure 9.

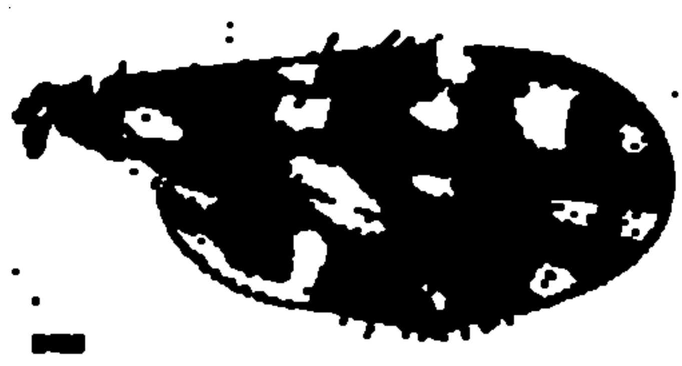


Fig. 9. Improved Binary Image

Another important feature to identify between different species of mosquitoes is the wings' skeleton, formed by the veins and cells. Therefore, one of the options to find the skeleton is to find the pixels that conform the perimeter of objects in an image, in these research the objects are mainly the cells. The function used works by assigning a pixel as part of the perimeter if it is nonzero and has at least a 0 pixel neighbor. The resulting image is shown on figure 10

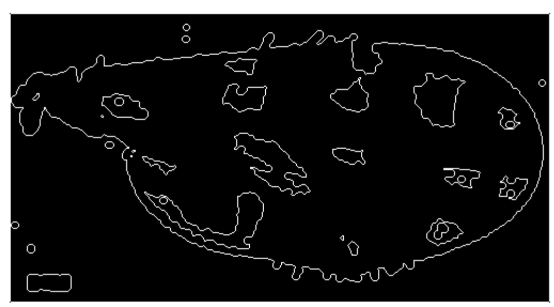


Fig. 10. Wing's skeleton

To acquire more important information from the wings, once the skeleton was found, we obtained the location of intersecting points using a function provided by [12], it is also possibly to calculate the distance between two intersecting points, if necessary. The resulting image is shown on figure 11

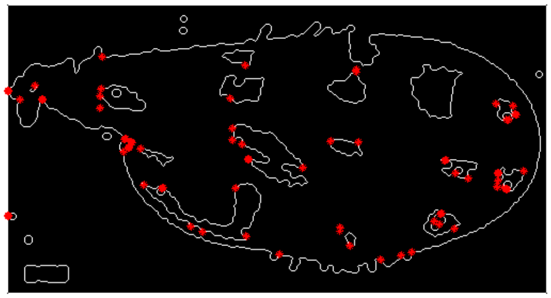


Fig. 11. Wing's skeleton -Intersection Points

With a binary image of the wing, one of used techniques, was to seek for the cells as if they were circles, and measure its centers and radii. One of the most common methods to find defined shaped objects is the Hough Transform, to find arbitrary objects the Generalized Hough Transform and to find circles the Circular Hough Transform (CHT). Circular Hough Transform, uses the parametric equations of the circle shown on equation 7 and 8.

$$x = x_0 + rcos\theta \tag{7}$$

$$y = y_0 + rsin\theta \tag{8}$$

Where:

x_0 and y_0 are the circle's center coordinates.

Therefore, when computing there are three parameters to search for: x_0, y_0 and the radius, which implies a high computational performance, memory and larger time required. Then, to reduce these inconveniences it was necessary to define the radius of the circle we were searching for. In this case we used a range between $(20, 26)$ pixels. The computation reduces to a 2-Dimensional problem. Circles are drawn, for every point on the edge of an object, points work as the center of the circle and have the radius specified before. Normally, the Circular Hough Transform manages a 3D array to determine the presence of circles, in this research the third dimension has an already set range of values. On each iteration, when a circle is found with the required specifications, its information is saved on the array. This array counts the times each circle passes trough "coordinates of each edge point". [5] Once it finishes it finds and keeps only the circles with the highest count, these means that similar circles were removed [5].

The resulting image is shown on figure 12.

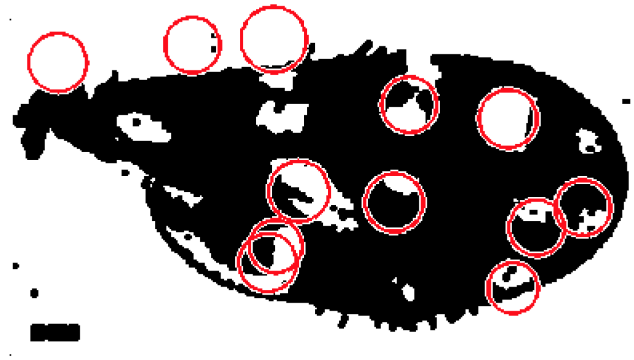


Fig. 12. Identified cells as circles on Binary Image

To improve results sometimes it was necessary to suppress circles that do not correspond to cells in images. For this purpose, *imclearborder* function was used. The resulting image is shown on figure 13.

Fig. 13. Identified cells as circles on Binary Image without borders

For this kind of research is important to have redundancy on the obtained information to provide real and trusty results. Therefore, even though the majority of the cells were already identified, it is indispensable to label, enumerate and locate each of them. Another outstanding feature, was the metric which is a value in the range of $(0, 1)$ that defines "how round" is an object. Metric was important to compare between different wings. Metric is given by equation 9, showing that it is a relation between the area and the perimeter. The closer it gets to 1, it means the cell is approximately round.

$$metric = \frac{4 * \pi * area}{perimeter^2} \tag{9}$$

The resulting image is shown on figure 14.

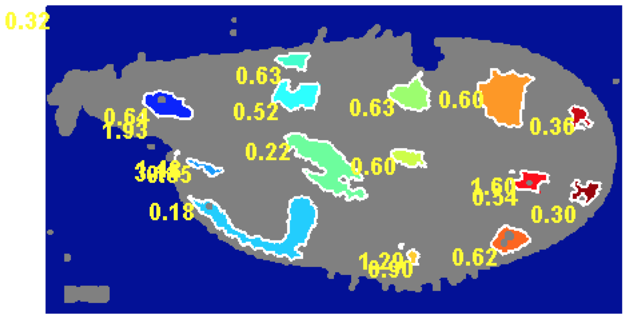


Fig. 14. Identified cells and wing, labeled with its corresponding metric

On figure 15 are displayed only the cells, to have a better approach to pattern recognition.

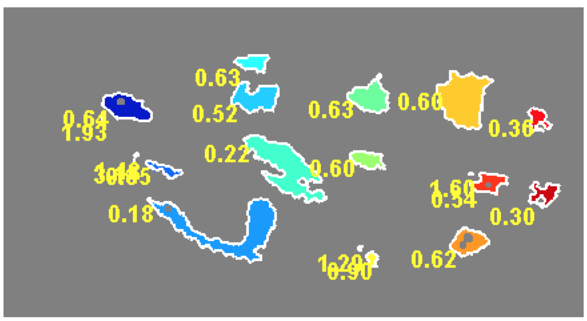


Fig. 15. Identified cells, labeled with its corresponding metric

III. Experiments and Results

In this research the equipment used to obtained the images was a *Zeiss V20 microscope*, coupled with a *Sony DSC camera* to take pictures of the wings. Images were required to be on a lossless compression format such as PNG or TIFF.

The results after applying the proposed algorithm are shown on table I. Gray-Scale Image gave a proper beginning for the image processing, and with Gaussian filter, noise was reduced. Once the image was converted to binary, most of the cells were easier identified by the human's eye, but there still was not an automatic labeled identification. On the improved binary image it is clearly visible that most of the noisy pixels, were removed and cell contours gained shape. This allowed to became more precise on the next steps. The number of cells, was mostly obtained by identifying them as circles. In some wings, the results in this step improved, when removing the wing's border, as we can see on figure 12 and 13; but it was not the same case on figures presented on table I. This is the reason why it was necessary to have both images, with and without wing's border. After having an approximate number of cells, it was important to identify its location, label each of them and count them again to compare with the number of cells as circles. On table II is present important information, such as the threshold level required to convert to binary image, the number of circles and objects (boundaries), with and without wing's border.

TABLE I
Processed Images- Results 1

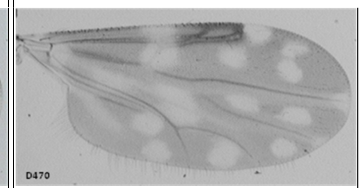
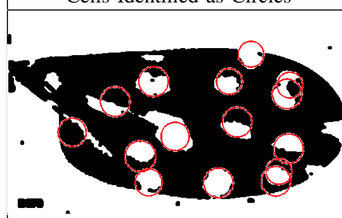
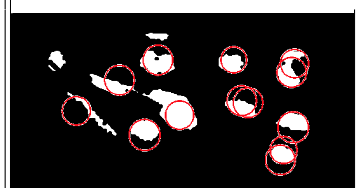
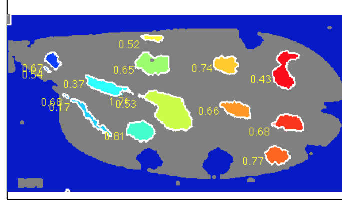
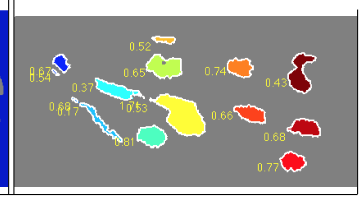
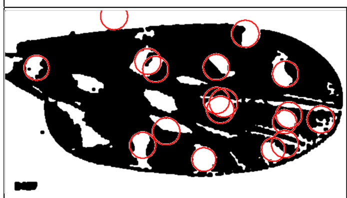
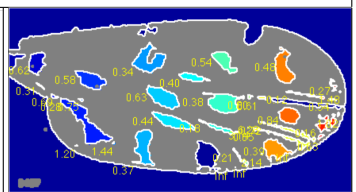
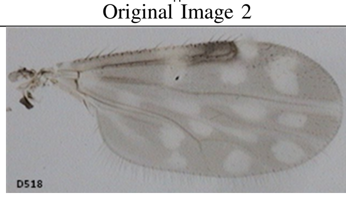
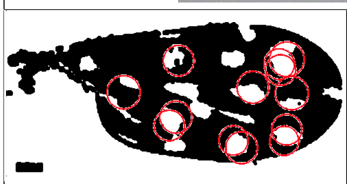
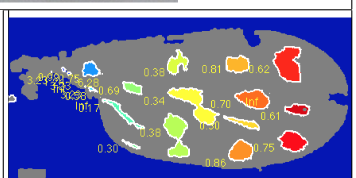
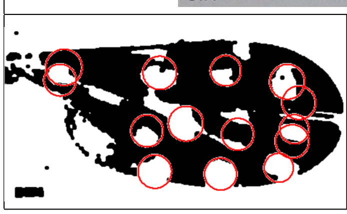
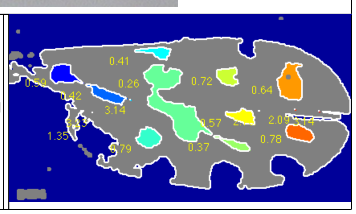
Original Image-Test 1	Filtered Gray-Scale Image
	
Binary Image	Improved Binary Image
	
Cells Identified as Circles	Cells Identified as Circles (No borders)
	
Identified Boundaries	Identified Boundaries (No borders)
	

TABLE II
Processed Images-Data Results 1

Level (Gray-Scale to Binary Image)	0.6627
Number of cells-Circles (Wing's Border)	15
Number of cells-Circles (No Wing's Border)	13
Number of cells-Boundaries	17
Number of cells-Boundaries (No Wing's Border)	16

The algorithm was applied with different species, the main results are shown on table

TABLE III
PROCESSED IMAGES- RESULTS 1

Original Image 1	
	
	
Original Image 2	
	
	
Original Image 3	
	
	

IV. CONCLUSION

Mosquitoes pattern identification through their wings implies: finding specific features as the ones treated on this research. Specially obtaining information of the cells, such as number, geometry and location. The size of each cell is not an accurate data because it depends most on the mosquito's size and physical health but not in its belonging specie. That is the reason, why metric could be a more relevant information because it gives a relation between area and perimeter that could be analyzed between other mosquitoes. The skeleton and corresponding intersecting points, may be more important tools when working with mosquitoes from other species, where landmarks and vein patterns are the target of the investigation. However, it helped to improved the algorithm and have a different view of the wings. With the developed algorithm, mosquitoes could be faster and efficiently identified through human's vision and could be an important tool for people that is venturing on this area. This algorithm could also, be a first step to recollect information and develop neural training to create a data base and therefore a large scale automate identification system.

REFERENCES

[1] University of Florida. *"Featured Creatures"*. Aug 2013. Web. 02 May 2016.
http://entnemdept.ufl.edu/creatures/aquatic/biting_midges.htm

[2] Eldridge, B. *Medical Entomology: A Textbook on public Health and Veterinary Problems Caused by Arthropods.* Davis: Springer Science+Business Media, B.V.,2004.

[3] Universitat de Valencia. *"1.2.2 Conversión a escala de grises"*.n.d. Web. 25 Feb. 2016.
http://www.uv.es/gpoei/eng/Pfc_web/generalidades/grises/grey.htm

[4] Universidad Nacional Autónoma de México.*"Tratamiento de imágenes en Matlab"*n.d. Web. 25 Feb. 2006.
http://profesores.fi-b.unam.mx/maixx/Biblioteca/Librero_Telecom/Libro_Matlab/Imagenes/Imagenes.pdf

[5] Dembele, F. *"Object Detection Using Circular Hough Transform"*.Nov 2010. Web. 02 May 2016.
http://wcours.gel.ulaval.ca/2015/a/GIF7002/default/5notes/diapositives/pdf_A15/lectures%20supplementaires/C11d.pdf

[6] LEEDS. *"Zeiss SteREO Discovey. V20 Stereomicroscope"*. Web. 05 May 2016.
http://www.leedsmicro.com/Forensic_Microscopes-Zeiss_SteREO_Discovery.V20_Stereomicroscope.html

[7] The University of Auckland. *"Gaussian Filtering"*. 25 May 2010. Web. 23 Feb 2016.
⟨https://www.cs.auckland.ac.nz/courses/compsci373s1c/PatricesLectures/Gaussian%20Filtering_1up.pdf⟩

[8] Gonzalez, R. *Digital Image Processing Using Matlab*. New Jersey: Prentice Hall,2002.

[9] Matlab, The Mathworks,Inc., Natick, Massachusetts, United Sates.

[10] Aydin, A. *"EE584 Machine Vision"*. 2012. Web. 26 Feb 2016.
⟨http://www.eee.metu.edu.tr/~alatan/Courses/EE584LECTURES/rv02.pdf⟩

[11] The College of Engineering at the University of Utah, viewed March 1 2016.
⟨http://www.coe.utah.edu/~cs4640/slides/Lecture11.pdf⟩

[12] Fong, A. *"Skeleton Intersection Detection"*.18 Dec 2003. Web. 3 Mar 2016.
⟨http://www.mathworks.com/matlabcentral/fileexchange/4252-skeleton-intersection-detection/content/find_skel_intersection.m⟩

[13] Rhody,H. *"Lecture 10: Hough Circle Transformation". 11 Oct 2005. Web. 15 Mar 2016.*
⟨https://www.cis.rit.edu/class/simg782/lectures/lecture_10/lec782_05_10.pdf⟩

[14] Rizon, M. *Object Detection Using Circular Hough Transform*. 2005. Web. 15 Mar 2016.
⟨http://dspace.unimap.edu.my/xmlui/bitstream/handle/123456789/11349/ajas2121606-1609.pdf?sequence=1⟩

[15] Matlab and Image Processing Toolbox R2016a. *"Identifying Objects"*. 2016. Web. 2 Mar 2016.
⟨http://www.mathworks.com/help/images/examples/identifying-round-objects.html?refresh=true⟩

[16] Poly, D. *"Geometric Morphometrics"*.2012. Web. May 2016.
⟨http://www.indiana.edu/~g562/Lectures/Lecture%201%20-%20Introduction%20to%20Geometric%20Morphometrics.pdf⟩

[17] Universidad Nacional de Quilmes. *"Segmentación por Umbralización-Método de Otsu"*. OCt 2005. Web. May 2016.
⟨http://iaci.unq.edu.ar/materias/vision/archivos/apuntes/Segmentacin%20por%20umbralizacin%20-%20Mtodo%20de%20Otsu.pdf⟩

[18] Utrecht University. *"Mathematical Morphology"*. Web. May 2016.
http://www.cs.uu.nl/docs/vakken/ibv/reader/chapter6.pdf