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Characteristics Analysis and Detection Algorithm of Mosquitoes

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Abstract

The systematic detection and elimination of mosquitoes is a valuable process, the results of which could be important in the fight against Malaria. In this study, image processing is used, allowing the researchers to detect the mosquitoes and their locations. Mosquitoes' physical characteristics, territorial and behavioral patterns were also analyzed through recognition technology. It is found that mosquitoes can be detected and differentiated by their physical, territorial and behavioral patterns through these methodologies. In addition to mosquitoes, flies and bees are also included in this study and were analyzed for their patterns, as well as their distinguishing features. Size, number of objects, proboscis, body shape, color, antennae, hind legs, and shape parameters were all factors considered for mosquito detection with image processing. All these informations were used in the Mosquito Detection Algorithm. This study provides characteristic descriptions of all three insects and statistical analysis of the data found.

Keywords: *mosquito, pattern, mosquito model, detection, malaria*

1. Introduction

Human Malaria and some other diseases such as yellow fever and dengue are transmitted by mosquitoes [1]. Particularly, the female mosquitoes are dangerous vectors for infesting humans with such diseases. Malaria transmission can be experienced in houses, forests, farms and any other vector disease environment. There are some mosquitoes which bite humans routinely. These routine bites with vectors carrying infectious diseases affect millions of people per year [2, 3]. Although there are others mosquitoes which do not bite humans, they are nonetheless vectors for animal diseases such as dengue, Zoonosis, etc. [4, 5]. Every year about one million people lose their lives due to Malaria caused mainly by Mosquitoes. Among this figure, about 85% are Children under the age of 5 years old [4]. Most Malaria cases that result in the loss of life occur in developing countries with 90% of malaria deaths occurring in Africa. The economic impact of malaria deaths due to mosquito bites in developing countries is enormous. The effects include low life expectancy rates with a high infant mortality rate, all of which bring reduction in productivity and an increase in government's budget on health at the expense of other social amenities.

This study focuses on the detection of mosquitoes through image processing techniques in order to destroy them with laser technologies. LASER technology is a preventative measure that could be used to avoid mosquito bites thereby saving lives and cutting down personal and national budgets on healthcare.

2. The Proposed Algorithm

2.1. Characterstics and Pattern Analysis for Mosquitoes with Flies and Bees

The frequency of mosquitoes varies from 200Hz to 700Hz and the average frequency is about 600Hz [6]. Generally, mosquitoes have one proboscis, two wings, an abdomen with characteristics such as white and gray lines, six legs (two front legs, two mid legs and two long special hind legs), a head and a throat. The body of a mosquito is especially long and thin. The length of an adult mosquito is varied and it is usually 16mm or longer (0.6 inch) [7]. The weight of a mosquito is found to be up to 2.5mg (0.04 grains). All Mosquitoes have slender bodies with three segments namely; (i) head, (ii) thorax and (iii) abdomen. A mosquito's head has a

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specialized response sensor for receiving information and for feeding [8]. It has two eyes and a long pair of segmented antennae. A Mosquitoes' antennae have multiple purposes which can be used as a sensing organ to detect other insects, to smell, to touch, and to take in moisture from the air [9]. The compound eyes of an adult mosquito develop in a separate region of the head. The hexagonal pattern only becomes visible when the carapace of the stage with square eyes is molted [10]. The head also has an elongated forward-projecting which is "stinger-like" proboscis used for feeding, and two sensory pulps. Male mosquitoes have longer maxillary pulps while the females have shorter ones. Some female mosquitoes have elongated proboscis. A mosquito's thorax is a locomotion system and is connected to the three pairs of legs and a pair of wings. Generally, the traveling range for a mosquito is around 75-100 miles. Mosquitoes can fly for up to four hours continuously at 1km/h to 2km/h (0.6-1mph) [11]. At night, the *Anopheles* mosquito can travel up to 12km (7.5miles) [6]. The usual life span of a mosquito is up to 30 days or more. A comparative study of the three insects such as Mossquito, Fly, and Bee [12-14] has shown in Figure 1, Figure2, and Figure 3, that, the body shape of both flies and a bee is fatter and thicker than a mosquito and their legs are also comparatively shorter.

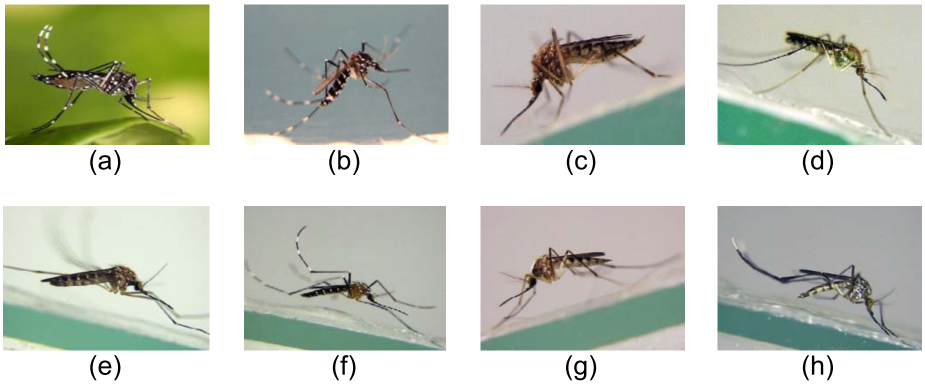


Figure 1. Images of Different Types of Mosquitoes

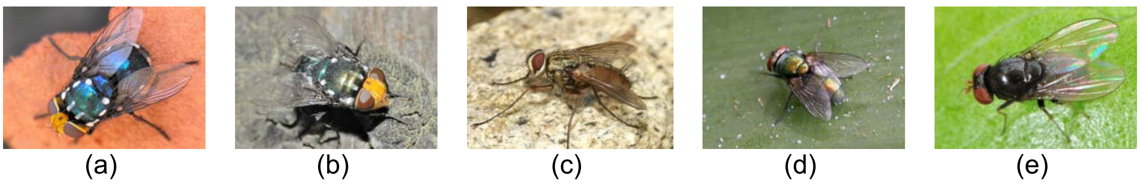


Figure 2. Images of Different Types of Flies

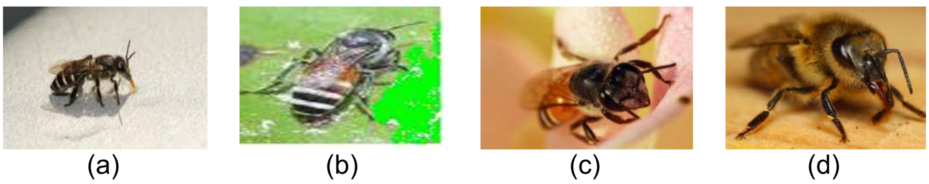


Figure 3. Images of Different Types of Bees

The proboscis too is somewhat shorter and in some instances there is no proboscis at all. Both bees and flies have speckled hair on their bodies, unlike mosquitoes which lack this type of characteristic. A comparative analysis of mosquitoes to bees and flies helps to detect mosquitoes and differentiate them from other insects shown in Table 1, Table 2, and Table 3. Bees have economic and industrial value and are also environmentally friendly. However, flies and mosquitoes can have a negative impact on the environment and health and can serve as a causative agent of Malaria.

Table 1. Characteristics of Different Types of Mosquitoes

Species	Head	Thorax	Abdomen	Object
Aedes aegypti	Proboscis: Dark; Pulps: Tipped with silvery-white; Clypeus: White scales.	Wings Scales dark; Legs color: Tarsal segment 5 is entirely white; White basal bands 2*6 for Hind legs and 3 for mid & forelegs.	Scutum: Lyre shaped, White scales.	30
Aedes albopictus (Stegomyia albopicta)	Pulps: Tipped with silvery-white; Clypeus: Black.	Wings Scales dark; Legs color: Tarsal segment 5 is entirely white; White basal bands 2*6 for Hind legs and 3 for mid & forelegs; Thorax: Sides are many silvery-white.	Scutum: One middle silvery-white stripe down.	23
Aedes vexans	Proboscis: Dark, Pulps: Dark.	Wings Scales dark; Legs color: Tarsal segment is entirely narrow white; narrow White basal bands 2*6 for Hind legs and 3 for mid & forelegs.	Shape: V, Color: Pale.	23
Culex territans	Proboscis: Dark, Pulps: Dark	Wings Dark, narrow; Legs color: Dark.	Color: Narrow APICAL bands.	15
Culex restuans	Proboscis: Dark; Edge is light white, Pulps: Dark.	Wings Dark, narrow; Legs color: Dark; some white spots; Thorax: Patches; pale scales.	Dark & white basal bands, scutum: Copper color; rarely 2 pale spots.	19
Deinocerites cancer	Proboscis: Dark; Antenna longer than proboscis, Pulps: Dark.	Wings Dark, narrow; Legs color: Dark.	Color: Copper brown.	15
Ochlerotatus bahamensis	Proboscis: Dark, Pulps: White tipped.	Wings Dark, narrow; Legs color: Hind legs dark with White basal bands.	Sputum: lines of golden & white scales.	17
Ochlerotatus infirmatus	Proboscis: Dark; Pulps: Dark.	Wings Dark, narrow; Legs color: Dark.	Color: Dark scale with basal;	23
Ochlerotatus triseriatus	Proboscis: Dark; Pulps: Dark.	Wings Dark; narrow; Legs color: Dark; Thorax: patches of silver-white scales.	Scutum: Dark; Legs are white of edge.	30

Table 2. Characteristics of Different Types of Flies

Species	Head	Thorax	Abdomen	Object
Amenia alboma culata	No proboscis; Post orbits yellow to orange; metallic dark blue; bright orange color face.	Dark blue-green to bluish violet; Head of male golden orange; Shiny white spots pattern.	12 mm; shiny white pattern; Scutellum with three pair of marginal setae.	52
Amenia leonina	No proboscis; Head of male golden Yellow. Post orbits yellow to orange.	Dark Blue-Green to bluish violet.	12 mm; Scutellum with 3 pairs of marginal setae.	68
Dexia rustica	No Proboscis; Color: Brown, white.	Dark; Legs are thin and short; Brown, dark.	Brown-dark; speckle.	108
Lucilia cuprina	No Proboscis; Red eyes.	Silvery head.	8 mm; Green metallic.	56
Neomyia sp.		Black.	5 mm; Black.	72

Table 3. Characteristics of Different Types of Bees

Species	Head	Thorax	Abdomen	Object
Apis andreniformis	Probocis: 2.80 mm; pulps: black stripes on the legs.	Tibia & dorsolateral: 8 or fewer; Thorax: 70-90 mm; Pigmentation: Blackish;	A circular body shape; Length: 47-54 um.	*29*
Apis florea	Proboscis: 3.27 mm.	Pigmentation: Yellowish.	Index: 2.86.	35
Honey bee (Apis mellifera)	Proboscis: yellow band; Pulps: Pomeranian brown.	Stocky body; Brown; dark coloration; Thorax: *Nigra*, heavy dark pigmentation of the wings.	Blackish, or *mellifera*, rich dark brown; color: yellow band.	31

2.2. Detection Process Analysis and Proposed Algorithm

Identifying the mosquitoes' physical shape is very important in the process of detection. If it is possible to identify a mosquito's physical shape, then the information could be further processed for detection and position tracking. As a result the Robotic visions are then able to effective as the target and destroy mosquitoes. The image processing used also detected the mosquito's position by territorial and behavioral pattern analysis. This implies that further research could be done where it is possible to show how robotic vision can detect mosquitoes by using this method, so that the destruction of mosquitoes is more efficient and successful. The algorithmic processes are presented in the Figure 4.

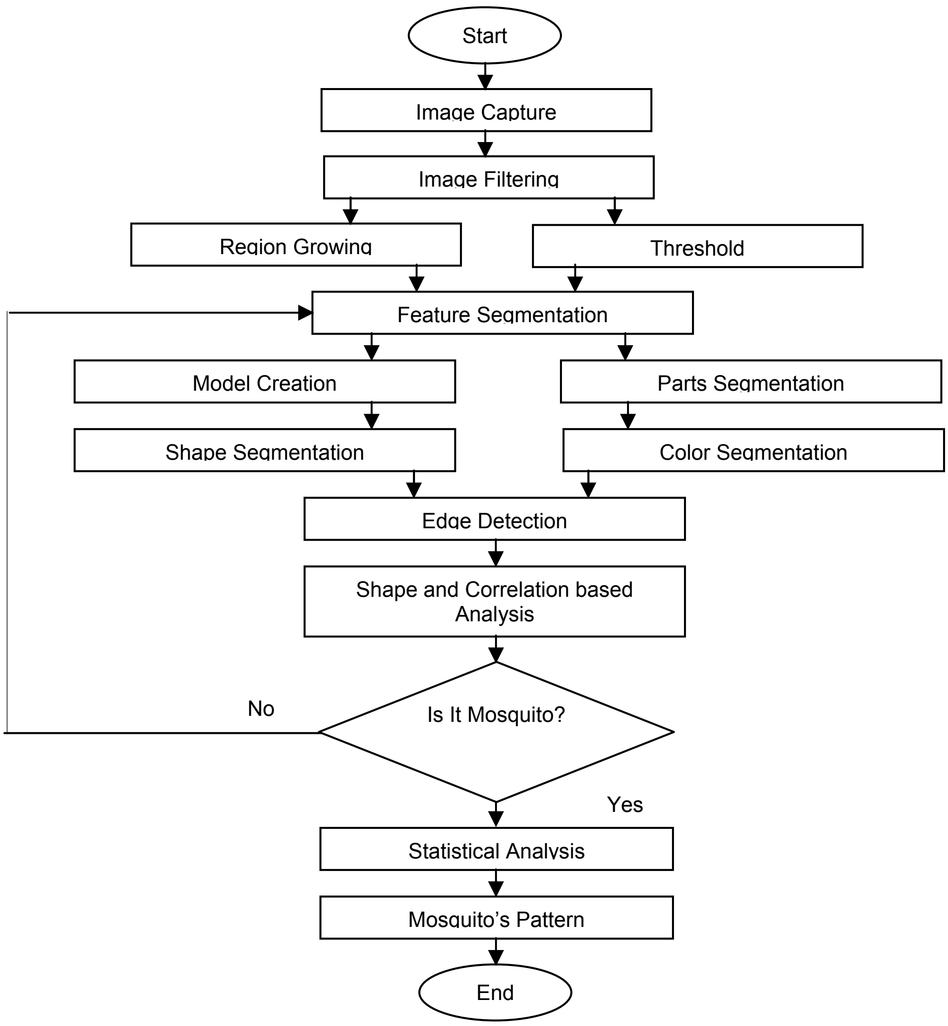


Figure 4. Mosquito's pattern detection algorithm (MPDA)

There are many methods for detection of the moving object. The background subtraction method is effective to detect for slow motion flying mosquito. The background images pixel value and the detected moving images pixel are not the same [15]. The difference between these two values can be defined as the region of interest (ROI) for mosquito detection. The segmentation of background pixel and the targeted mosquito's pixel value is important to differentiate the modeling and updating [15, 16].

The Adaptive Surendra Algorithm (ASA) is for background estimation and the Inter-Frame Differencing Algorithm (IFDA) is effective for flying Mosquito detection. The frame differencing, background extraction and updating, background subtraction and motion detection [15] is important for Mosquito detection. The template image is important for post processing which can be analyzed for morphological filtering to eliminate the tiny noisy region. Image filtering is important to eliminate the noise of image and smoothing the image to get the efficient pixel value. The background segmentation would be helpful by using thresholding and region growing process which is helpful for feature segmentation. The body parts of Mosquito are complex thus flying Mosquito detection is very difficult. In this case the model creation and body parts analysis is important to analyze and detect mosquitoes. The legs of Mosquitoes are not the same as other insects. The segmentation process is useful for mosquitoes' detection. The shape of the Mosquito can be captured by model setting. Especially herein the rotated rectangular model has been created to detect the flying or moving Mosquito. The abdominal parts are special stylist such as white and black-gray segmented color line.

3. Research Method

This study consists of two methods: one is an external (behavioral) analysis and the other method is an image processing analysis. The image processing part was done by Matlab software. Noise was eliminated from the film by a noise rejection method using image processing.

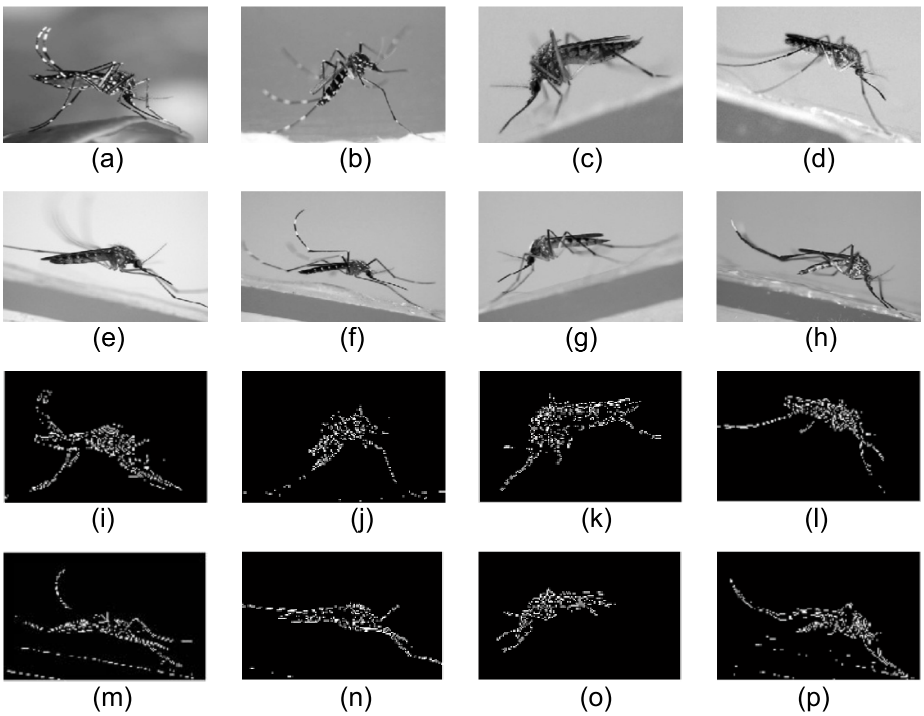


Figure 5. Mosquitoes pattern images (i)-(p) from (a)-(h) gray images (of Figure 1)

The noise extraction and rejection program was also developed with Matlab. The camera was used to differentiate mosquitoes, bees and flies. Then the image processing data which was collected on the mosquitoes, flies and bees was organized and analyzed through statistical methods such as histograms that produced the area, mean, median, and standard deviation etc. After a detailed characteristic study derived from the films images was collected, a recognizable behavioral and territorial pattern emerged. The insects' locations and their pattern characteristics ratios can be found in the histogram analysis. The histogram was applied to analyze insect size, number of objects, proboscis, body shape, color, antennae and shapes, etc.

Whether at home or out of home, one can grab Mosquito(s) and put it/them inside the 15cm x13cm x2cm Mosquito box. The images are captured by GigE 4900 and Keyence XG H200M camera. The experiment has been analyzed by Halcon 11.0 software. During the image processing, the median filter is used to eliminate the noisy interference.

Features which were included in the table are antennae, proboscis, hind legs, size and body shape are detected by edge detection, stains, pitch, edge width, edge angle, edge positions, statistical analysis and its characteristics. Fourier descriptors, as well as a differential coefficient and distributed processing were used in the pattern for recognition [17]. The mosquito's positional pattern was observed and the Edge pattern of the mosquito detected by Matlab Edge processing which is shown in Figure 5, and Figure 6. The results show the mosquito's positional histogram. The imaging process allows researchers to determine where the mosquito is, and even make predictions based on analyzing the patterns as to where the mosquito will likely be in the future as in shown in Figure 5(i)-(p). The histogram analysis also showed that the mosquito's territory is smaller than that of flies and bees. This can be seen in Figure 6.

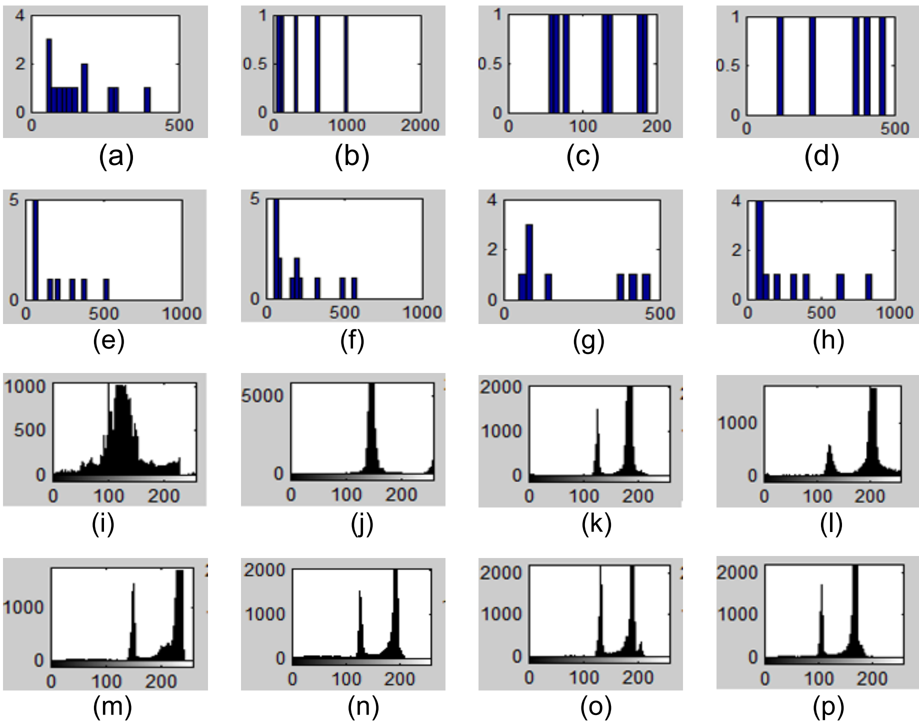


Figure 6. Statistics of Mosquitoes; (a)-(h) histogram, and (i)-(p) area histogram

From all the figures of the territorial edge patterns, it can be concluded that a mosquito's territorial pattern shape is narrow and long where the pattern for flies is almost triangular or 'V' or 'Z' or 'Curve' or 'Λ' in shape as in Figure 5(i)-(p). The patterns of Flies are similar to 'rectangular' or 'arrow head' shape as in Figure 7(f)-(j). For Bees, it is round and not very clear. These results are shown clearly in Figure 8(e)-(h). The histogram of the mosquitoes shows more spikes in consistency and a narrower width than flies and bees in Figure 6(a)-(h), Figure 7(k)-(o), and Figure 8(i)-(l). It is remarkable that the histogram reveals that the territory of a mosquito is much smaller than that of Flies and Bees in Figure 6(i)-(p), Figure 7(p)-(t), and Figure 8(m)-(p).

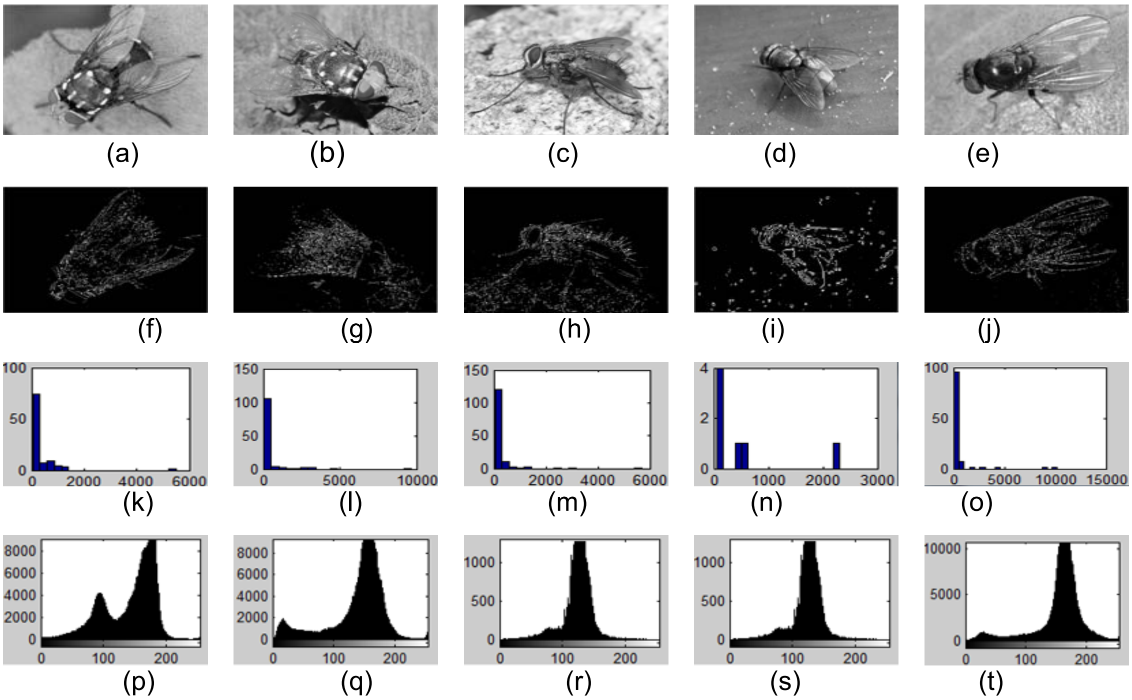


Figure 7. Pattern and Statistical Images of Flies; (a)-(e) gray images (from Figure 2), (f)-(j) edges pattern, (k)-(o) histogram, and (p)-(t) area histogram

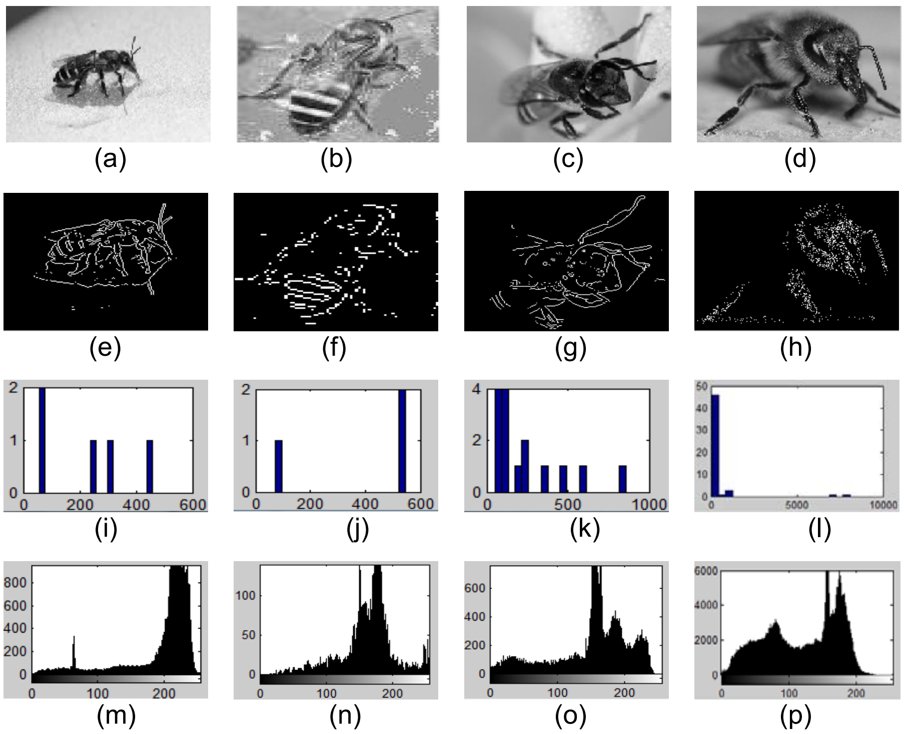


Figure 8. Pattern and Statistical Images of Bees; (a)-(d) gray images (from Figure 3), (e)-(h) edges pattern, (i)-(l) histogram, and (m)-(p) area histogram

4. Results and Discussion

From the results, it is evident that Mosquitoes have long proboscis than Flies and Bees. The body shape of flies has two round forms, and they have shorter and thicker legs than Mosquitoes. The abdominal part of the Mosquito is narrow slender and White-Gray stripe. However, the flies have no White-Gray stripe on the abdomen. The head of the flies is also larger, as is the thorax. Observations also show that a flies coloring is a metallic blue or green color with brown, dark gray coloring spread throughout. Its body length is less than 12mm which is smaller than a mosquito's size and body length. Mathematically, it can be determined that, the body shape of fly is linear, and the main sections of the body are fully narrow cylinders.

Bees are more similar to flies than mosquitoes. However, their body shape pattern is linear in its spherical shape with proboscis. Its proboscis is shorter than that of mosquitoes'. The body length is normally less than 16 mm whereas the mosquito's body length is a minimum of 16 mm. It was also observed that the bee has very small yellow spikes on its body. Table 4 summaries the physical characteristics of Mosquitoes, Flies and Bees.

Table 4. Pattern Characteristics of Mosquitoes, Flies and Bees

	Body Shape	Leg	White segment	Proboscis (mm)	Body Shape	Length (mm)	Recognition Ratio
Mosquitoes	Narrow Slender	Long	yes	Long (~6)	Λ or V or Z or curve	>16	Higher
Flies	Fat Cylinder	short	no	Short (~2)	Linear or Part of rectangle	5~12	Lower
Bees	Fat Cylinder	short	no	Shorter (<2)	Linear or Part of circle	<16	Lower

Most of the mosquitoes have angular shaped bodies with an abdomen part, thorax & head. The legs are long, the abdomen is slender and narrow with dark color though some of them have white circular lines. The hind legs are both light and dark in color and are thin. The minimum length of mosquitoes is about 16mm which is very important for pattern recognition design. These recognition ratios of Mosquitoes are higher whereas the recognition ratio of Flies and Bees are lower as given in Table 4. The angle between the head and abdomen is approximately $\pm 135^o$ (ø) while that of the reverse side which changes during flying is $\pm 235^o$ (ø). Hence the body shape is like a 'V or Λ' but if it is viewed with the addition of the hind legs, then the pattern is more like a 'Z' as shown in Figure 9(a)-(c). If the thorax shape of the mosquito is more curved then it would seem to be a fly or bee as indicated in Figure 9(d), and Figure 9(e). The proposed demo model of mosquitoes for this pattern shape has been mentioned in the cross section of the pattern as in Figure 9(a).

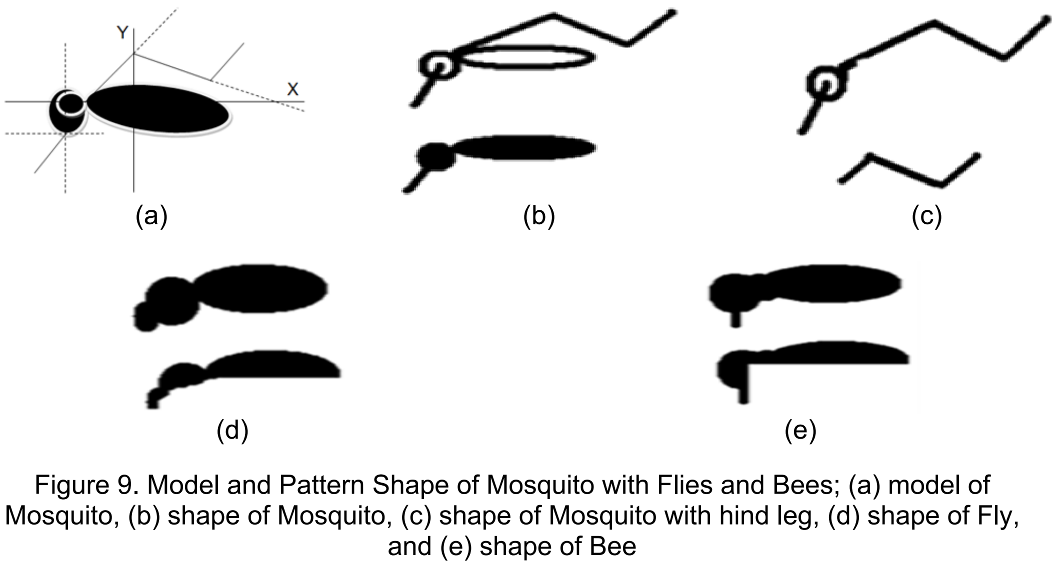


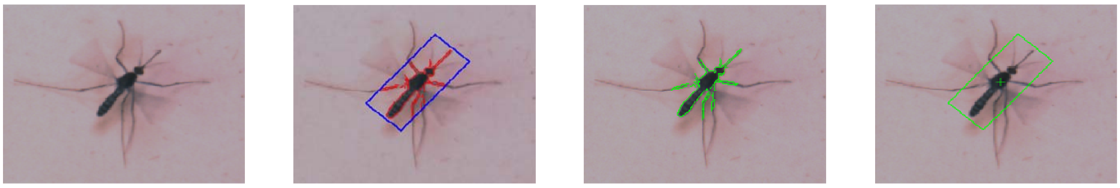
Figure 9. Model and Pattern Shape of Mosquito with Flies and Bees; (a) model of Mosquito, (b) shape of Mosquito, (c) shape of Mosquito with hind leg, (d) shape of Fly, and (e) shape of Bee

All of the features have been considered to detect the edges of the Mosquito as shown in Figure 10. The recognition ratio of Mosquitoes, bees and flies are similar as explained in Table 5. It is assumed that the recognition ratio is the major axis length divided by the minor axis length in pixels. The major axis length is the total length of head, thorax, and abdominal part of the mosquito. The proboscis can be ignored for lack of Robotic vision because it is so thin and not clearly visible for imaging when the Mosquito is flying. The minor axis length has been considered the length of abdomen or thorax part as width of maximum pixel value in minor axis. This ratio will ensure that the Mosquito and its flying positions.

Table 5. Recognition Ratio of Mosquitoes, Flies and Bees

	Length (L pixel)	Width (W pixel)	$R_{L/W}$=L / W
Mosquitoes	284.606	53.815	5.289
	220.272	35.203	6.257
	285.732	56.991	5.032
	193.204	32.692	5.909
	250.276	46.791	5.349
	183.114	43.782	4.153
	278.785	53.345	5.226
	185.483	24.925	7.442
Flies	588.596	280.781	2.096
	497.653	232.982	2.136
	489.230	248.110	1.972
	455.539	186.843	2.438
	489.230	248.110	1.972
Bees	113.054	34.363	3.290
	204.662	60.754	3.369
	554.116	180.360	3.072
	204.662	60.754	3.369

If the major axis length is L in pixel, the minor axis length is W in pixel the recognition ratio can be obtained from $R_{L/W}$=L/W [18]. The Mosquitoes, Flies, and Bees minimum recognition ratio are 4.153, 1.972, and 3.072, respectively and the maximum recognition ratios are 7.442, 2.438, and 3.369, respectively. Therefore it can be defined that the mosquito's recognition ratio is relatively higher. After comparing the length and width, it can be signify that the length is bigger and the width is smaller of the Mosquito. In this phenomenon it can be proceeded to differentiate and detect the Mosquito in Figure 10.



(a) (b) (c) (d)

Figure 10. Mosquito Detection (a) original image (b) create model with edges (c) shape model based edges detection (d) correlation based model detection

The shape and correlation based analysis can be confirmed by the experimental tests and it can be signified to detect and track position of the Mosquito as presented in Figure 11. The statistical method can determine detection information, parts, segmentation, positions and the moving angle of the mosquito. The all determined information would be helpful to destroy the Mosquito by LASER system. The contour information of images can be provided by Halcon software. During the detection, the background of the image has been subtracted by thresholding and region growing method so that it can be detected as quickly as possible as shown in Figure 11.

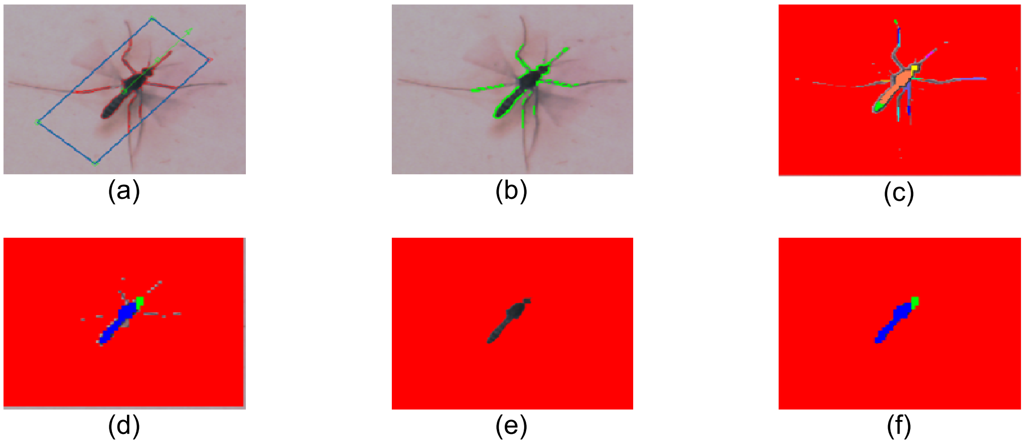


Figure 11. Background Segmentation for Mosquito Detection; (a) filtering & model creation, (b) pattern detection, (c) threshold without model, (d) region growing, (e) threshold of original image, and (f) region growing image after threshold applied

After setting up the model, the background subtraction method is applied. Next, the threshold image and the region growing image run process is adopted to detect the mosquito one by one in the real flying space. Before detection, it is necessary to process the optimization of statistical analysis. The grabbing image can be processed and the Mosquito can be detected. The Mosquito are flying from one position to another position then the rotated rectangular are searching the pattern of the model in Figure 12.

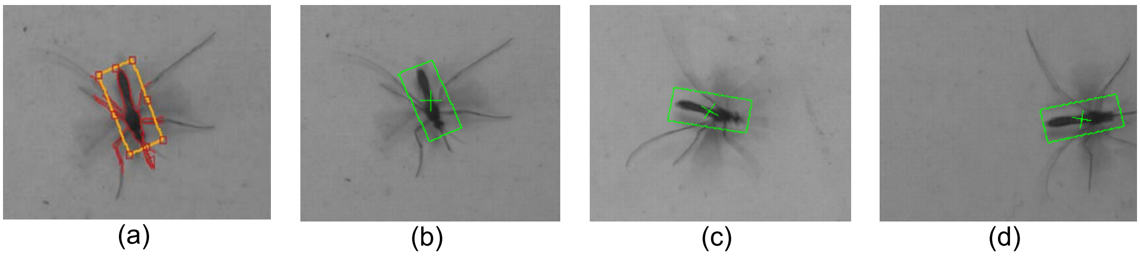


Figure 12. Detected Mosquito after Model Setting; (a) model setting, and (b)-(d) detected in diffetent positions during flying time

The whole detection processed has been analyzed by Halcon Software. About 20 Mosquitoes were grabbed and put inside the Mosquito box for experimental exercise. In this process the applied algorithm is effective and the statistical results have shown stability. During detection process, minimum score, maximum score, detection time and angular movement has been observed as given Table 6. The time to detect the Mosquito is very important. Each Mosquito detection process minimum time is 1.95 ms and the maximum extended time is 4.87 ms that is effective and stable for detection of Mosquito. It can be considred as the significant results to design a Mosquito destroy controller [19].

Table 6. Statistical Results for Mosquito Detection

Range	Score	Time for each Mosquito detection (ms)	Angle (ø)
Minimum	60%	1.95	-1.21°
Maximum	100%	4.87	248.04°

5. Conclusion

Mosquitoes are the key actors in the spread of Malaria in developing nations. In order to prevent Malaria, it is necessary to eliminate its cause. Finding ways of detecting mosquitoes through behavioral, territorial and physical patterns have been the goal of this research project. Data were collected through the use of image processing, characteristics study and pattern analysis. In future, the pattern information would be helpful for designing a mathematical model of Mosquito to innovate 'Mosquito Robot for Destroy Mosquito (MRDM)' which will detect and destroy the Mosquito to minimize the risk of Malaria disease. Application of a proposed demo model is useful for future research to make a robotic vision system for detecting and destroying Mosquito effectively and efficiently.

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