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PROCESS AND SYSTEM FOR AUTOMATIC IDENTIFICATION OF THE LARVAE OF *AEDES ALBOPICTUS* AND *AEDES AEGYPTI*

Field of the Invention

[0001] The present invention generally relates to the prevention of mosquito-borne diseases, and more particularly to the process and system for automatic identification of the larvae of *Aedes albopictus* and *Aedes aegypti*.

Background of the Invention

[0002] Dengue (DEN) viruses belong to the genus flavivirus, within the family Flaviviridae. There are at least 70 flavivirus species, among which the most important human pathogens are the DEN viruses, yellow fever virus, and the Japanese (JE) and tick-borne encephalitis viruses. Diseases caused by the 4 serotypes of DEN virus (DEN1-4), dengue fever (DF) or dengue hemorrhagic fever/shock syndrome (DHF/DSS), are endemic or epidemic in tropical and sub-tropical countries around the world. In a manner similar to that of yellow fever, dengue is transmitted between humans by the domestic mosquito vector, *Aedes aegypti*.

[0003] Dengue fever is the most common vector-borne viral disease affecting humans worldwide, with an estimated 50 million infections occurring in tropical and subtropical regions each year. In Singapore, dengue virus is transmitted by the *Aedes* mosquitoes – *Aedes albopictus* and *Aedes aegypti*, the latter being the primary vector. Past experiences have revealed that there is strong correlation between dengue outbreaks and the *Aedes aegypti* population. To control dengue outbreaks, there is a need to monitor and control the population of the *Aedes aegypti* population.

[0004] To monitor and control the *Aedes aegypti* population in Singapore, NEA has placed over 4000 ovitraps in dengue and *Aedes*-prone areas. The ovitrap - a black cylinder with a piece of cardboard - has been used as a monitoring device for *Aedes* mosquitoes in Singapore since the 1970s. Similar devices have been used around the world to monitor mosquito activity but unlike these, Singapore's ovitrap was designed to eliminate the mosquitoes that hatch from the eggs. The black colour of the ovitrap attracts female



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mosquitoes to lay their eggs. When the eggs hatch and develop into adults, they cannot fly out of the device and die inside the trap. Apart from controlling the mosquito population, the larvae in the ovitraps can be identified and counted to monitor the populations of different mosquito species. Unlike malaria-transmitting mosquitoes that stick to rural areas and swampy waters, the *Aedes* mosquito prefers fresh, clean water and it breeds largely indoors, needing only tiny pools of water to lay its eggs. Since clean water is used inside the ovitrap, the *Aedes aegypti* and *albopictus* are the two primary mosquito species found in the ovitrap.

[0005] The mosquito identification process is currently performed by trained experts using manual microscope. The process is both time consuming and laborious as large quantities of larvae found in thousands of ovitraps need to be identified. To speed up the larva identification process, a computer-aided identification process and system is desired.

Summary of the Invention

[0006] One embodiment of the present invention provides a computerized process for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus* from the images that may contain the larvae of *Aedes aegypti* and/or *Aedes albopictus*. One embodiment of the process comprises obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*, identifying boundary pixels of the comb objects, transforming the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles to provide an averaged angle, and comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the computerized process.

[0007] In another embodiment of the process, the operation of identifying boundary pixels comprises checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

[0008] In another embodiment of the process, the operation of transforming the identified boundary pixels into vectors comprises randomly selecting a boundary pixel as a

first point, choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector, and choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector, thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

[0009] Another embodiment of the present invention provides a computerized process for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus* from the images that may contain the larvae of *Aedes aegypti* and/or *Aedes albopictus*. One embodiment of the process comprises obtaining an image containing the larvae of *Aedes aegypti* and/or *Aedes albopictus*, wherein the image is converted into a grayscale image if necessary, converting the grayscale image into a binary image with a preset number of thresholds, eliminating background noise, eliminating irregularly shaped objects to obtain remaining objects, identifying boundary pixels of the remaining objects, transforming the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA), obtaining a median ORA for all objects in a single image, obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images, and comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the computerized process.

[0010] In another embodiment of the process, the operation of eliminating the background noise comprises filling up of holes in the image by dilation operation, performing erosion operation, and removing objects with area either larger or less than predetermined numbers of pixels and the objects that contain image boundary pixels considered as boundary object.

[0011] In another embodiment of the process, the operation of eliminating the irregularly shaped objects comprises identifying the boundary pixels of each object, calculating the center of the boundary pixels, calculating the distance of each boundary pixel from the center, identifying peaks in the boundary pixels using all the distances for all

the boundary pixels of the object, and eliminating the objects if their number of peaks is outside of the preset threshold values.

[0012] In another embodiment of the process, the operation of identifying peaks in the boundary pixels comprises comparing the distance of one selected boundary pixel from the center with that of a preset number of its neighboring pixels, whereby if the distances of its neighboring pixels are smaller, the selected pixel is considered as a peak.

[0013] Another embodiment of the present invention provides a system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample. One embodiment of the system comprises a computer-readable medium having computer-executable instructions for performing a process comprising obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*, identifying boundary pixels of the comb objects, transforming the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles to provide an averaged angle, and comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the system.

[0014] In another embodiment of the system, the operation of identifying boundary pixels comprises checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

[0015] In another embodiment of the system, the operation of transforming the identified boundary pixels into vectors comprises randomly selecting a boundary pixel as a first point, choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector, and choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector, thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

[0016] Another embodiment of the present invention provides a system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample. One embodiment of the system comprises a computer-readable medium having computer-executable instructions for performing a process comprising obtaining an image containing

the larvae of *Aedes aegypti* and/or *Aedes albopictus*; wherein the image is converted into a grayscale image if necessary, converting the grayscale image into a binary image with a preset number of thresholds, eliminating background noise, eliminating irregularly shaped objects to obtain remaining objects, identifying boundary pixels of the remaining objects, transforming the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA), obtaining a median ORA for all objects in a single image, obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images, and comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the system.

[0017] In another embodiment of the system, the operation of eliminating the background noise comprises filling up of holes in the image by dilation operation, performing erosion operation, and removing objects with area either larger or less than predetermined numbers of pixels and the objects that contain image boundary pixels considered as boundary object.

[0018] In another embodiment of the system, the operation of eliminating the irregularly shaped objects comprises identifying the boundary pixels of each object, calculating the center of the boundary pixels, calculating the distance of each boundary pixel from the center, identifying peaks in the boundary pixels using all the distances for all the boundary pixels of the object, and eliminating the objects if their number of peaks is outside of the preset threshold values.

[0019] Another embodiment of the present invention provides a system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample. One embodiment of the system comprises an image acquiring module, a microprocessor module electronically coupled with the image acquiring module, having a computer-readable medium comprising a storage medium for storing input, intermediate and output data, and embedded computer-executable instructions, and a user interface electronically coupled with the microprocessor allowing a user to input instructions and receive the output from the microprocessor; wherein the embedded computer-executable instructions perform the process comprising obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*, identifying boundary pixels of the comb objects, transforming

the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles to provide an averaged angle, and comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the system.

[0020] Another embodiment of the present invention provides a system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample. One embodiment of the system comprises an image acquiring module, a microprocessor module electronically coupled with the image acquiring module, having a computer-readable medium comprising a storage medium for storing input, intermediate and output data, and embedded computer-executable instructions, and a user interface electronically coupled with the microprocessor allowing a user to input instructions and receive the output from the microprocessor, wherein the embedded computer-executable instructions perform the process comprising obtaining an image containing the larvae of *Aedes aegypti* and/or *Aedes albopictus*; wherein the image is converted into a grayscale image if necessary, converting the grayscale image into a binary image with a preset number of thresholds, eliminating background noise, eliminating irregularly shaped objects to obtain remaining objects, identifying boundary pixels of the remaining objects, transforming the identified boundary pixels into vectors, calculating the angles between two adjacent vectors, averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA), obtaining a median ORA for all objects in a single image, obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images, and comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image, thereby reporting the results to the user of the system.

[0021] The objectives and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0022] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0023] FIG 1 shows one exemplary image of lower part of the abdomen region of the larvae of (a) *Aedes aegypti* and (b) *Aedes albopictus* with the comb objects being magnified.

[0024] FIG 2 shows a flowchart of the automatic process for identification of the larvae of *Aedes aegypti* and *Aedes albopictus* in accordance with one embodiment of the present invention.

[0025] FIG 3 shows a grayscale image of the larva of *Aedes albopictus* with a 0-255 scale.

[0026] FIG 4 shows a binary image converted from the image shown in FIG 3 under one threshold value.

[0027] FIG 5 shows a color inverted image of the image shown in FIG 4.

[0028] FIG 6 shows a background noise-eliminated image of the image shown in FIG 5.

[0029] FIG 7 shows the distance 74 and angle 73 between the center point 71 and a boundary pixel 72.

[0030] FIG 8 shows the comb object of *Aedes aegypti* and its shape signature.

[0031] FIG 9 shows the comb object of *Aedes albopictus* and its shape signature.

[0032] FIG 10 shows an exemplary irregularly shaped object and its shape signature.

[0033] FIG 11 shows an irregularly shaped objects-removed image of the image shown in FIG 6.

[0034] FIG 12 shows the sharp edges of the comb objects of the *Aedes aegypti* and *albopictus* larvae.

[0035] FIG 13 is an illustration showing the calculation of the angle of a boundary pixel in accordance with one embodiment of the present invention.

[0036] FIG 14 shows a functional block diagram of the system in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0037] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0038] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0039] The present invention provides a process for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus*. In principle, the automatic identification process takes the advantages of the distinctive comb objects present in the larvae of *Aedes aegypti* and *Aedes albopictus*. Briefly, the automatic identification process comprises acquiring the images in which the larvae of *Aedes aegypti* and *Aedes albopictus* might be present, eliminating background noise and irregularly shaped objects from the images, and calculating the larvae representation angles (LRA); thereby identifying the larvae of *Aedes aegypti* and *Aedes albopictus*.

[0040] FIG 1 shows one exemplary image of lower part of the abdomen region of the larvae of (a) *Aedes aegypti* and (b) *Aedes albopictus* with the comb objects being magnified. The inventors of the present invention discovered that the distinctive shapes of the comb objects present in the larvae of *Aedes aegypti* and *Aedes albopictus* could be exploited for their automatic identification.

[0041] Now referring to FIG 2, there is provided a flowchart of the automatic process for identification of the larvae of *Aedes aegypti* and *Aedes albopictus* in accordance with one embodiment of the present invention. Briefly, when the automatic identification process starts 10 by acquiring and convert if necessary images to grayscale image 20, then sets a threshold for converting the grayscale images into black/white binary images 30, then converts the grayscale images into binary images by the preset threshold 40, perform elimination of background noise from the binary images 50, perform elimination of irregularly shaped objects from the binary images 60, then repeat the operations 30-60 with each increment to the threshold if the threshold is less than the maximum value of the preset threshold 70, then perform identification of larva 80 if the

threshold used for filtering is larger than the maximum value; and the process ends when the identification is accomplished 90.

[0042] Now a more detailed description is provided for the operations of the automatic identification process.

[0043] The acquisition of images 20 can be achieved by any conventional image acquisition devices. The acquired images are preferably stored in RGB (red, green, blue) format. The exemplary images of the lower end of the abdomen region of the *Aedes aegypti* and *albopictus* larvae are shown in FIG 1. Then, the input larva images are converted to grayscale images; the conversion can be done according to the conventional scales, for example 0-255 scale. FIG 3 shows a grayscale image of the larva of *Aedes albopictus* with a 0-255 scale.

[0044] The setting of threshold values 30 for converting the grayscale images into binary images can be determined experimentally. It is possible to set a single threshold value for the conversion from the grayscale images to binary images. However, in light of the variations in acquiring the images, a series of threshold values (e.g., from 0.05 to 0.5) are preferably used to binarize the image into black and white images. In the operation of conversion to binary images 40, the grayscale image is binarized using the threshold value provided; if the value of a pixel in a grayscale image is higher than the threshold, it is given a value of 255, else it is given a value of 0. The binary image will contain comb objects from the larva, background noise, and other objects. FIG 4 shows a binary image converted from the image shown in FIG 3 under one threshold value.

[0045] Before further operations, the binary image can be optionally inverted its color, i.e., $0 \rightarrow 255$ and $255 \rightarrow 0$. The inversion will be advantageous when a white boundary is shown over a black background when the Matlab software is used because it can only operates on images with white objects and black background. FIG 5 shows a color inverted image of the image shown in FIG 4.

[0046] The performance of elimination of background noise 50 comprises filling up of holes in the image by dilation operation and performing erosion operation subsequently, and removing the objects with area either less or larger than predetermined numbers of pixels and those objects that contain image boundary pixels considered as boundary object. The size-based elimination removes the objects that are too small or too big. The thresholds for the judgment can be determined experimentally. For example, in the

examples below, objects with area less than 1310 pixels and objects with area more than 2831 pixels are eliminated. For the objects that have areas between 1310 and 2831 pixels, they undergo shape-based elimination of irregularly shaped objects discussed in detail herein below. FIG 6 shows a background noise-eliminated image of the image shown in FIG 5.

[0047] The performance of elimination of irregular shaped objects 60 comprises shape-based elimination of objects from the images. The shape-based elimination first identifies the boundary pixels of each object remaining in the image. For every pixel in each object, if any of the neighboring pixels (e.g., 4 nearest neighbors is used here) is a background pixel, the pixel is considered a boundary pixel. Then, the center of the object is calculated from the boundary pixels. In one embodiment, the center of the object is calculated according to the following equation (1):

[0048]

$$\text{center of object} = \left(\frac{\sum x}{n}, \frac{\sum y}{n} \right) \quad (1)$$

[0049] where n is the number of boundary pixels, and x and y are the pixel positions (coordinates).

[0050] For every pixel along the boundary, the distance and angle from the center are calculated and stored. It is to be noted that the center of the object can be calculated by any other known methods. FIG 7 shows the distance 74 and angle 73 between the center point 71 and a boundary pixel 72.

[0051] After getting all the distances and angles for all the boundary pixels of the object, the peaks in the boundary pixels of the object are then identified. In one embodiment, the peaks are identified by simply comparing the distance of one selected boundary pixel from the center with that of a preset number of its neighboring pixels. For example, for a chosen boundary pixel, its distance is used to compare with that of the nearest 6 pixels (3 nearest pixels on the left and 3 nearest pixels on the right). If the distances of the 6 nearest pixels are smaller, the chosen pixel is considered as a peak. The operation is repeated for all the pixels in the boundary to find other peaks. The identified peaks can be plotted to show the shape signatures of the objects. FIGs 8, 9 and 10 show the comb object of *Aedes aegypti* and its shape signature, the comb object of *Aedes albopictus* and its shape signature, and an exemplary irregularly shaped object and its shape signature, respectively.

[0052] When all of the peaks of an object have been identified, the peaks are used to remove irregularly shaped objects. Threshold for judging whether an object is an irregularly shaped one can be determined by the complexity of the objects remained in the image after the elimination of background noise. In principle, objects with more than four peaks or less than 2 peaks can be removed. However, in practical applications the threshold for the peaks of removable objects can be set higher. In one embodiment, objects with more than 9 peaks and objects with less than 2 peaks are considered as irregular objects and removed. FIG 11 shows an irregularly shaped objects-removed image of the image shown in FIG 6.

[0053] Then, the threshold used in the conversion of the grayscale image to binary image is compared with the preset maximum threshold value 70. If the threshold used is less than the preset maximum value, another incremented threshold value is then selected and the process repeated until a maximum threshold value is reached. All the objects that are stored in the memory will be used in the final identification operation.

[0054] The identification of the *Aedes aegypti* larva 80 is performed as follows. It is observed that the comb object in the *Aedes aegypti* larva has four sharp edges at the top, bottom and the sides whereas the comb object in the *Aedes albopictus* larva has only 2 sharp edges at the top and bottom. FIG 12 shows the sharp edges of the comb objects of the *Aedes aegypti* and *albopictus* larvae.

[0055] The boundary pixels of the object can be transformed into vectors of uniform length. By measuring the angles between adjacent vectors, the inventors of the present invention discovered that the angles could be used to differentiate *Aedes aegypti* from *Aedes albopictus*. It is to be appreciated that the uniformed vectors are advantageous in for example saving the computational power; however the length of the two vectors may be varied so long as the angles from the two vectors are suitable for operation of the present invention. It is preferably that the length is about from 3 to 8 pixels. As shown in FIG 13, there is provided an illustration showing the calculation of the angle of a boundary pixel in accordance with one embodiment of the present invention. To find the angles along the boundary pixels, a pixel is randomly chosen from the boundary pixels, called the first point. Next, from the first point, a second point is chosen which is five pixels away along the boundary in the clockwise direction. The first vector is formed using these 2 points. The second vector is formed in the same way by finding the third point which is 5

pixels away along the boundary from the second point. In this manner, all the vectors along the outline for each of the boundary pixels are created. Then, the angles between 2 adjacent vectors are calculated and stored.

[0056] In one embodiment, 10 biggest angles from each object are averaged to represent the object. The average angle is called the object representation angle (ORA). Then, the median value of all ORAs for all objects in a single image is obtained. As discussed above, different threshold values are used in binarizing the images; thus each threshold value (eg, from 0.05 to 0.5) produces an image that may contain several objects. After the median ORAs of all the objects in all the images generated by different threshold values are found, the median value of the median ORAs is calculated, and then the resultant median value of the median ORAs is used for identification. The threshold value for the median of the median ORAs in differentiating the *Aedes albopictus* and *Aedes aegypti* can be experimentally determined. In the conditions used by the inventors of the present invention, the threshold value for the median of the median ORAs was determined at 137 degrees; thus if the median of the median ORAs is less than 137 degrees, the larva is classified as *Aedes albopictus*; otherwise it is classified as *Aedes aegypti*.

[0057] The present invention also provides a system for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus*. FIG 14 shows a functional block diagram of the system in accordance with one embodiment of the present invention. The system 100 comprises an image acquisition module 110 for acquiring images of the larvae, a microprocessor 120 electronically coupled with the acquisition module for receiving and storing the acquired images, and a user interface 130 electronically coupled with the microprocessor for a user to input instructions and view the results. The microprocessor comprises a storage medium 121 and embedded computer executable programs 122 embedded therein for performing the process of the present invention.

[0058] The following examples are provided for the sole purpose of illustration; it is by no means intended to limit the scope of the present invention.

[0059] Examples

[0060] The algorithm above was used to calculate the median of the median ORAs for the 10 *Aedes aegypti* images and 13 *Aedes albopictus* images.

[0061] Results

[0062] Using the threshold angle of 137 degrees, images with the median of the median ORAs greater than or equal to 137 degrees were classified as *Aedes aegypti*, and images less than 137 degrees are classified as *Aedes albopictus*. All *Aedes aegypti* images were classified correctly while 10 out of 13 *Aedes albopictus* images were classified correctly. The results are summarized herein below in Table 1.

[0063] Table 1. CRA results for the *Aedes albopictus* and *Aedes aegypti* images

Albo1	Albo2	Albo3	Albo4	Albo5	Albo6	Albo7	Albo8	Albo9	Albo10	Albo11	Albo12	Albo13
114.8	136.5	128.0	132.0	121.0	106.1	150.0	116.0	141.0	88.0	130.2	142.0	91.5

Aeg1	Aeg2	Aeg3	Aeg4	Aeg5	Aeg6	Aeg7	Aeg8	Aeg9	Aeg10
139.0	145.5	167.4	137.0	137.3	162.0	155.0	144.8	145.0	138.3

[0064] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the invention scope is not so limited. Alternative embodiments of the present invention will become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

CLAIMS

What is claimed is:

1. A computerized process for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus* from the images that may contain the larvae of *Aedes aegypti* and/or *Aedes albopictus*, comprising:

obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*;

identifying boundary pixels of the comb objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles to provide an averaged angle; and

comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;

thereby reporting the results to the user of the computerized process.

2. The computerized process of claim 1, wherein the operation of identifying boundary pixels comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

3. The computerized process of claim 1, wherein the operation of transforming the identified boundary pixels into vectors comprises:

randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

4. A computerized process for automatic identification of the larvae of *Aedes aegypti* and *Aedes albopictus* from the images that may contain the larvae of *Aedes aegypti* and/or *Aedes albopictus*, comprising:

obtaining an image containing the larvae of *Aedes aegypti* and/or *Aedes albopictus*;
wherein the image is converted into a grayscale image if necessary;

converting the grayscale image into a binary image with a preset number of thresholds;

eliminating background noise;

eliminating irregularly shaped objects to obtain remaining objects;

identifying boundary pixels of the remaining objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA);

obtaining a median ORA for all objects in a single image;

obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images; and

comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;

thereby reporting the results to the user of the computerized process.

5. The computerized process of claim 4, wherein the operation of eliminating the background noise comprises:

filling up of holes in the image by dilation operation;

performing erosion operation; and

removing objects with area either larger or less than predetermined numbers of pixels and the objects that contain image boundary pixels considered as boundary object.

6. The computerized process of claim 4, wherein the operation of eliminating the irregularly shaped objects comprises:

- identifying the boundary pixels of each object;
- calculating the center of the boundary pixels;
- calculating the distance of each boundary pixel from the center;
- identifying peaks in the boundary pixels using all the distances for all the boundary pixels of the object; and
- eliminating the objects if their number of peaks is outside of the preset threshold values.

7. The computerized process of claim 6, wherein the operation of identifying the boundary pixels of each object comprises:

- checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

8. The computerized process of claim 6, wherein the operation of identifying peaks in the boundary pixels comprises:

- comparing the distance of one selected boundary pixel from the center with that of a preset number of its neighboring pixels;
- whereby if the distances of its neighboring pixels are smaller, the selected pixel is considered as a peak.

9. The computerized process of claim 4, wherein the operation of identifying boundary pixels of the remaining objects comprises:

- checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

10. The computerized process of claim 4, wherein the operation of transforming the identified boundary pixels into vectors comprises:

- randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

11. A system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample, comprising:

a computer-readable medium having computer-executable instructions for performing a process comprising:

obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*;

identifying boundary pixels of the comb objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles to provide an averaged angle; and

comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;

thereby reporting the results to the user of the system.

12. The system of claim 11, wherein the operation of identifying boundary pixels comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

13. The system of claim 11, wherein the operation of transforming the identified boundary pixels into vectors comprises:

randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

14. A system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample, comprising:

a computer-readable medium having computer-executable instructions for performing a process comprising:

obtaining an image containing the larvae of *Aedes aegypti* and/or *Aedes albopictus*; wherein the image is converted into a grayscale image if necessary;

converting the grayscale image into a binary image with a preset number of thresholds;

eliminating background noise;

eliminating irregularly shaped objects to obtain remaining objects;

identifying boundary pixels of the remaining objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA);

obtaining a median ORA for all objects in a single image;

obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images; and

comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;

thereby reporting the results to the user of the system.

15. The system of claim 14, wherein the operation of eliminating the background noise comprises:

filling up of holes in the image by dilation operation;
performing erosion operation; and
removing objects with area either larger or less than predetermined numbers of pixels and the objects that contain image boundary pixels considered as boundary object.

16. The system of claim 14, wherein the operation of eliminating the irregularly shaped objects comprises:

identifying the boundary pixels of each object;
calculating the center of the boundary pixels;
calculating the distance of each boundary pixel from the center;
identifying peaks in the boundary pixels using all the distances for all the boundary pixels of the object; and
eliminating the objects if their number of peaks is outside of the preset threshold values.

17. The system of claim 16, wherein the operation of identifying the boundary pixels of each object comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

18. The system of claim 16, wherein the operation of identifying peaks in the boundary pixels comprises:

comparing the distance of one selected boundary pixel from the center with that of a preset number of its neighboring pixels;
whereby if the distances of its neighboring pixels are smaller, the selected pixel is considered as a peak.

19. The system of claim 14, wherein the operation of identifying boundary pixels of the remaining objects comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

20. The system of claim 14, wherein the operation of transforming the identified boundary pixels into vectors comprises:

randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

21. A system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample, comprising:

an image acquiring module;

a microprocessor module electronically coupled with the image acquiring module, having a computer-readable medium comprising a storage medium for storing input, intermediate and output data, and embedded computer-executable instructions; and

a user interface electronically coupled with the microprocessor allowing a user to input instructions and receive the output from the microprocessor;

wherein the embedded computer-executable instructions perform the process comprising:

obtaining a binary image of comb objects of the larvae of *Aedes aegypti* or *Aedes albopictus*;

identifying boundary pixels of the comb objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles to provide an averaged angle; and

comparing the averaged angle with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;
thereby reporting the results to the user of the system.

22. The system of claim 21, wherein the operation of identifying boundary pixels comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

23. The system of claim 21, wherein the operation of transforming the identified boundary pixels into vectors comprises:

randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.

24. A system for identifying the larvae of *Aedes aegypti* and *Aedes albopictus* in a sample, comprising:

an image acquiring module;

a microprocessor module electronically coupled with the image acquiring module, having a computer-readable medium comprising a storage medium for storing input, intermediate and output data, and embedded computer-executable instructions; and

a user interface electronically coupled with the microprocessor allowing a user to input instructions and receive the output from the microprocessor;

wherein the embedded computer-executable instructions perform the process comprising:

obtaining an image containing the larvae of *Aedes aegypti* and/or *Aedes albopictus*;
wherein the image is converted into a grayscale image if necessary;

converting the grayscale image into a binary image with a preset number of thresholds;

eliminating background noise;

eliminating irregularly shaped objects to obtain remaining objects;

identifying boundary pixels of the remaining objects;

transforming the identified boundary pixels into vectors;

calculating the angles between two adjacent vectors;

averaging a preset number of the biggest angles of one object to obtain an Object Representation Angle (ORA);

obtaining a median ORA for all objects in a single image;

obtaining a median of the median ORAs for all the images generated under the preset number of thresholds for converting the grayscale images; and

comparing the median of the median ORAs with a preset threshold value to identify *Aedes aegypti* or *Aedes albopictus* in the image;

thereby reporting the results to the user of the system.

25. The system of claim 24, wherein the operation of eliminating the background noise comprises:

filling up of holes in the image by dilation operation;

performing erosion operation; and

removing objects with area either larger or less than predetermined numbers of pixels and the objects that contain image boundary pixels considered as boundary object.

26. The system of claim 24, wherein the operation of eliminating the irregularly shaped objects comprises:

identifying the boundary pixels of each object;

calculating the center of the boundary pixels;

calculating the distance of each boundary pixel from the center;

identifying peaks in the boundary pixels using all the distances for all the boundary pixels of the object; and

eliminating the objects if their number of peaks is outside of the preset threshold values.

27. The system of claim 26, wherein the operation of identifying the boundary pixels of each object comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

28. The system of claim 26, wherein the operation of identifying peaks in the boundary pixels comprises:

comparing the distance of one selected boundary pixel from the center with that of a preset number of its neighboring pixels;

whereby if the distances of its neighboring pixels are smaller, the selected pixel is considered as a peak.

29. The system of claim 24, wherein the operation of identifying boundary pixels of the remaining objects comprises:

checking for every pixel a preset number of the neighboring pixels; whereby if any neighboring pixel for a selected pixel is a background pixel, the selected pixel is considered a boundary pixel.

30. The system of claim 24, wherein the operation of transforming the identified boundary pixels into vectors comprises:

randomly selecting a boundary pixel as a first point;

choosing a pixel being away from the first point in a preset number of pixels as a second point; wherein the first point and second point form a first vector; and

choosing a pixel being away from the second point in a preset number of pixels as a third point, where the third point is farther away from the first point than the second point; wherein the second point and third point form a second vector;

thereby all vectors along the boundary pixels for each of the boundary pixels are generated.