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Article

Retrieval of Time of Death Basing on Forensic Entomology through Digital Imaging

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Abstract: Digital investigation is one of innovative enhance in the field of forensic science. Investigating a crime scene is very crucial and challenging for both the police and investigating departments. As a novel solution for manual intervention, out research embellishes various studies and observations during the investigation. To digitize the investigations process, research motivated us biologically to present the simulation of various events present at the crime scene. The approach started with the bodily fluids, blood pooling, surface of the body lay down, oxidization after death ,skin tones observed and finally Sarcophagid flies. As a part of our research we demonstrate different approaches on various models to compare the real world photographic examples.
Keywords: Entomology, blow flies, image acquisition, time of death, entomology

1. Introduction

Entomologists do a vague research in finding the evidence at the crime scene. As a part of their investigation work, they impose their utmost knowledge in the preserve of evidence through the image of insects available in the surroundings of the dead body. To explain in court of justice they testify and produce insect related evidence in various stages of the insect life cycle. Succession of species may also help for investigation. Some insects prey on the fresh corpse as other relies on decomposed and decayed corpse. The investigators will also note the other insects that relay and feed up on the dead body. The vast study of the research determined post-mortem interval (PMI) is a dynamic approach and main objectives of doing medico autopsy as well as legal autopsy. The PMI can be determined from different observations through mortis of different types such as Algor Rigor, Livor eye changes, and coeliac contents etc in the hourly stages of the necropsy period. In addition to symptoms of putrefaction, the vermin's play the most considerable role as a evidence in reckoning PMI is done in the late post-mortem phase. Sarcophagus flies, typical flies which feed on larger vertebrate carcasses lay their eggs on soggy sectors, such as in particularly around the eye balls, snout, gullet and anus and

genitalia if exhibited. The larva stage of a fly is well known to be as maggot. These are nothing but the eggs with ovum with protectable shell lay by the flies. These eggs hatch within 24 hours and hundreds of flies can be appearing in place of the dead body. These grow day by day and shed their outer layer skin a number of times throughout its life time, the larvae, which each ecdysiast being called an instar, finally pupate grew into a fresh winged insect come into act on the dead body. Species and the ambient temperature are very important and noted as a particular observation in this instance of time from egg lying through star to pupae. The research was carried by remembering various instances occurred in child hood as well as seen in various post-mortem cases at hospitals, reading books and research articles based up on the 40 decomposed bodies which undergone for post-mortem perusal in the Department of Forensic Medicine and Toxicology at Government Medical College, Amritsar. Bodies were clusters depending upon the categorization of tetrad stages of decay like new, bloated, decay and dry. Signs of rotting like feeble colour transformations, freckling of skin, disgusting gerund of gases, bloating of features of the body, skin slippage which causes when blisters are formed, dissolving of skin or loosening of the meat, easy hair follicles, loosening of parts like finger nails and denticle, colliquative putrefacient transformation, adipocerous formation, environmental circumstances of viscera, degree of skeletonization of body etc were observed and noted for future research endeavours. Our research performs the task of analysing the image and using a set of transformations in the dead body to aid in predicting and estimating the time of death. This investigation is essentially having a predefined dataset provided in it. The user has the choice of selecting an image from the given dataset or can inject any image to test the result. The given dataset has a set of images which are in the binary files. These binary images give the redemption from the burden of converting a RGB image into a binary file. This lowers the time complexity. A basic GUI aids in an amiable representation that consists of a 'Load Image' button is created which helps user to select an image from already provided dataset. And an 'Analyze' button which helps the backend to process the user selected image and output is displayed in number of days passed since time of death.

2. Literature Review on Existing Proposals

There exists a need for a forensic entomologist, who estimates time of death by evaluating stages of Sarcophagus fly's growth on cadavers at a crime scene [1]. Also, it would take manual efforts for an entomologist to test the body, take and note visual observations, gather the insect evidences, determine stages of evolution of life cycle, calculate time of initial lying of eggs and then predict the circumstances regarding the time of death. And also inculcating the services of an entomologist incur huge cost of equipment; other equipments used may burden the government that opts for an entomologist to solve a case [2]. Disadvantages exists in this process are it takes lot of time to collect, preserve and predicting the evidences. It also incurs the cost of hiring an entomologist. The user has the choice of selecting an image from the given dataset [3]. This process can be continued for as much number of input images taken and produces the exact output without any doubt. A basic GUI aids in an amiable representation that consists of a 'Load Image' button which helps user to select an image from already provided dataset. And an 'Analyze' button which helps the backend to process the user selected image and output is displayed in number of days passed since time of death [4].

3. Implementation Methodology

Now a day's every this is digitizing so as to get the world in our palm in nano seconds. So, we focused the entire investigation work to be in a digitized process with the exiting algorithms in digital image processing. These techniques help us very much to get the digitized results in few seconds. The proposed system eliminates the need of an entomologist who manually does a long process as represents the result in long period of time. Sometimes this result may not provide the expecting and fruitful investigation results. But the software's main intention is to automate the services and functionalities of an entomologist. Instead of hiring an entomologist, paying more and waiting more times for results if we automate the working of an entomologist it becomes very easy, accurate and might potentially lower the cost of investigation. Software that predicts the accurate death times alike an entomologist which saves time. Comparatively an entomologist takes two to three days to analyse and predict the time, whereas the digitalization of working of an entomologist work saves both time and cost which this research does. Here compassion of Feasibility study means the scanning of issues to determine if it can find a solution productively. In other words, it is the inquiry of the possibilities of the suggested system; it studies the work potential, impact on the organization ability to survive user's requirement and efficient use of resources. This research primarily focuses on the extracting time of death from a given image. The user has an added advantage of selecting images from an already provided dataset [5]. This research is designed ergonomically which aids in ease of access. When user selects an image, it is loaded into the display screen of the GUI. On pressing the analyse button, in the background the image is processed. The worms in the image are segmented; each and every worm is taken apart and is labelled with a number. After the segmentation and labelling are done, each and every worm's height is extracted [6]. The worm with the highest height is extracted and based on that the time of death is predicted.

3.1.*Imaging of Evidences*

Photographic images are taken as examples for simulations in the digital process, which are very realistic to nature happenings. Realistic imaging gains an immense attention of the users of this digital investigation. For example game players, When the creators follow the realistic scenery as a background and the image in the game consists real word objects and colours seems to be as they are really running or wandering in the real filed to get the higher levels. Such applications attract the users all around the world and yield profits economically to the developers. Realistic photography is taken in this research. The photographs taken to observe the dead body whether it is rotten or not, color shades of the skin, whether any blood pools present, the skin discolouration and so on.

3.2.*Investigation process step by step*

There exists a numerous approach that affect the post-mortem look of a body. Here as a first step of investigation, the photographs at crime scene are taken. Firstly, the user, whoever it may be needs to select an image from in the dataset already provided. After the selection is done, on analysing the image the application provides the output in days passed since death [2]. The scope of this research is limited to a category of blowflies and its worm. It doesn't take into consideration the other categories of insects such as arthropods. The output of the research can be accessed by any user, whose intention is to find time of death using an image of a corpse and the observation of flies and other arthropod behaviours to criminal matters [3]. This research automates the process of an entomologist, by finding the time of death using image processing. Also, the forensic science, a branch of science which finds applications in course of a investigation to collect, preserve, and analyze scientific evidence. It also includes various applications on arthropods such as insects, arachnids, millipedes, and centipedes, crustaceans to criminal cases [4]. Basically, the research takes an image as a input and pre- processes it, measures the size of the insect, predicts the death time depending up on the maximum size of the insect[5]. The time of death is suspect able to changes. Since the time of death is dependent on the size of the insect and also the temperature. Primarily, this research focuses on blowfly, which belongs to insect family.

3.3.*Observation of Fly's Life Cycle*

The life cycle of the blow fly at a constant temperature of 70°F is illustrated in Figure 1, showing the time taken for each developmental stage from egg to adult; the blow fly undergoes several stages.

Stage/ Duration	Instar Images
Egg/ 23 Hours	
1st Instar/27 Hours	

2nd Instar/ 22 Hours	
3rd Instar/ 130 Hours	
Pupa/143 Hours	
Adult	

Figure 1. Evolution Stages of a Common Blow Fly

Stage 1: The adult Sarcophagus flies lays their eggs on the carcass especially at the opening organs like nose eyes gentles and vegina.

Stage 2: These eggs develop into larva or the maggots in 12 to 24 hours in a day.

Stage 3: The second stage larvae grow into molt and leave the skin as they pass in various developments Stages like

First - instars it grows to 5mm after 1.8 days in 24 hours

Second- instars it grows to 10 mm after 27 hours

Third – instars ir grows to 14 to 16 mm in 22 hours

Fourth – instars the larva grows in to 17 mm and burrows the surrounding soilin 130 hours

Fifth – instars adult flies come out of pupa cases after 140 hours

All the stages and the body decomposition details are illustrated in Table 1.

Table 1: Stage and Age of Corpse

Stage	Image Description	Time Duration	Cumulative Time (hrs)	Description

Egg	Tiny white oval-shaped eggs	23 hours	23 hrs	Eggs are laid by adult blow flies on decaying matter or carcasses.
1st Instar	Very small maggot (larva)	27 hours	50 hrs	The first larval stage after hatching begins feeding.
2nd Instar	Slightly larger maggot	22 hours	72 hrs	The larva molts into the second stage and continues feeding and growing.
3rd Instar	Larger maggot with more ridges	130 hours	202 hrs	Final larval stage; prepares for pupation.
Pupa	Hardened, brown case	143 hours	345 hrs	Inside the puparium, transformation into adult fly occurs (metamorphosis).
Adult Fly	Fully formed blow fly	—	345 hrs (~14.4 days)	Emerges from the pupal case, ready to lay eggs and repeat the cycle.

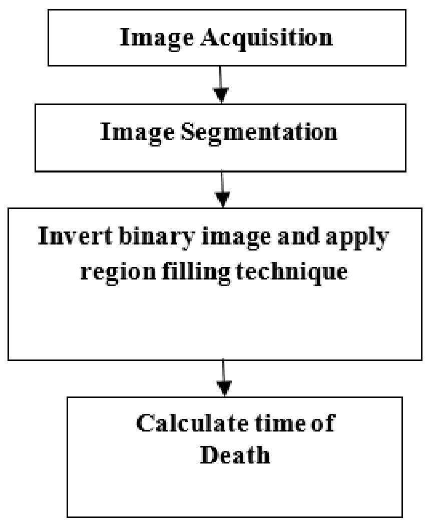


Figure 2. Algorithm followed to calculate the time of death of a corpse

3.4.*Image acquisition*

According to the first step illustrated in figure 2 recent trends in capturing images is with high mega pixel digital video camera technology [7] has developed sufficiently to capture of wandering freely insects with very sophisticated spatial and temporal resolutions. We used a high-resolution epsilon 140LC payload camera extremely with highly sophisticated features such as optical lens, flash exists externally, scale or ruler, hot-shoe bubble level. In experimental tests, a maggot (larva) which is alive was placed on a flat surrounding side to the graduated scale. The lens, then adjusted to capture so that the sensor level is parallel to the shooting surface. An image of the specimen captured and scale were both in focus with proper orientation for measurement. The process of image acquisition involves capturing light reflected from an object through a lens system, which focuses the rays onto a sensor to generate a digital representation. As illustrated in Figure 3, the lens barrel gathers light, directing it to the focal plane where the image is focused. This focused information is then projected onto the image plane, resulting in the final output image. This setup ensures that the details of the object, such as size and texture, are accurately recorded and processed.

Figure 3. Equipment for Digital Capture with insect rig

3.5.*Image Segmentation*

Image segmentation plays a critical role in the digital analysis of insect evidence for estimating the post-mortem interval (PMI). It involves partitioning an image into distinct regions to isolate the insect specimens, such as maggots or pupae, from the background. According to step 2 in figure 2 clearly explains that accurately segmenting the insects based on shape, colour, and texture, essential biological features such as instars stage, size, and body segmentation can be extracted. This information helps forensic investigators identify the developmental stage of the insect, which is directly linked to the time elapsed since death. Automated segmentation techniques thus enhance the precision and objectivity of evidence interpretation in forensic entomology.

3.5.1. ***Invert binary image and apply region filling technique***

Inverted Binary Image:

As in Figure 4 illustrated the black and white pixels were inverted so that the objects (insects) became black and the background became white. Highlighting pixels in an image with white color represent features, then assigning those pixels a class label.

Flood Fill Inverted:

As in figure 5 illustrated A flood fill operation was applied starting from the background. This fills the surrounding white area, leaving only the segmented objects untouched.

Region Filled Output:

As in figure 6 illustrated Combining the inverted flood-filled image with the inverted binary result gives a complete fill of segmented insect objects. However, in this case, the final region filling appears black due to all pixels being considered part of the background.

Figure 4: Inverted Binary Image

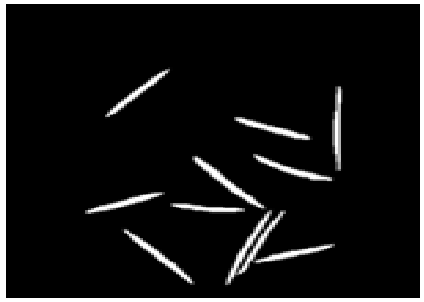


Figure 5: Flood filled Image

Figure 6: Region filled output

3.6.*Method implemented to calculate time of death.*

Experiments were done rigorously different stages of maggots and flies for getting accurate investigation results. Size of the insect is calculated with the help of experimented algorithm and outcomes of algorithm are compared with measurements [8] of grid count phenomena. The maggot is placed under the objective lenses of camera. The sensor then divides the image pixels of analogue stream. This stream of analogue pixels is pre-processed ad converted to digital signals [9]. The software that installed in our computer system processes the digital signals, find out the edges of the object in the image figure 5, and calculates the dimension. Here we need to calculate the circular dimensions as the maggot in the image may be circular some of the times. So, to do this we calculate the area by taking the circumference formula of a circle and inculcate in our measurement methods figure 6.

$$Cir = 2\pi r \qquad (1)$$

Where Cir = circumference
π = the constant pi,
r = radius of the circle

The two planes present in the camera give the distance. Since the Maggot's images are captured and placed on grid paper [10]. As illustrated in figure 7 Grid size is $1mm2$. Outlines of the maggot or insect are drawn on grid paper. Finally, area of the insect is measured by counting grids that are covered by insect.

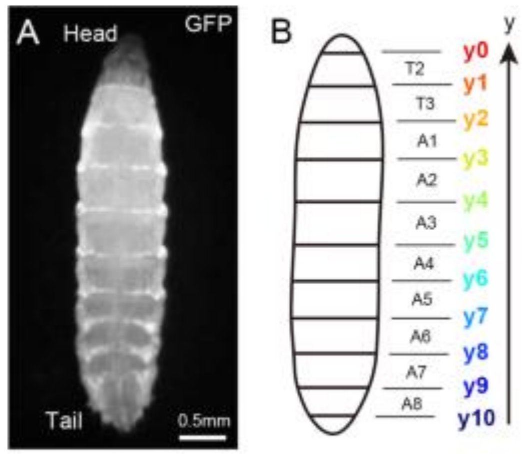
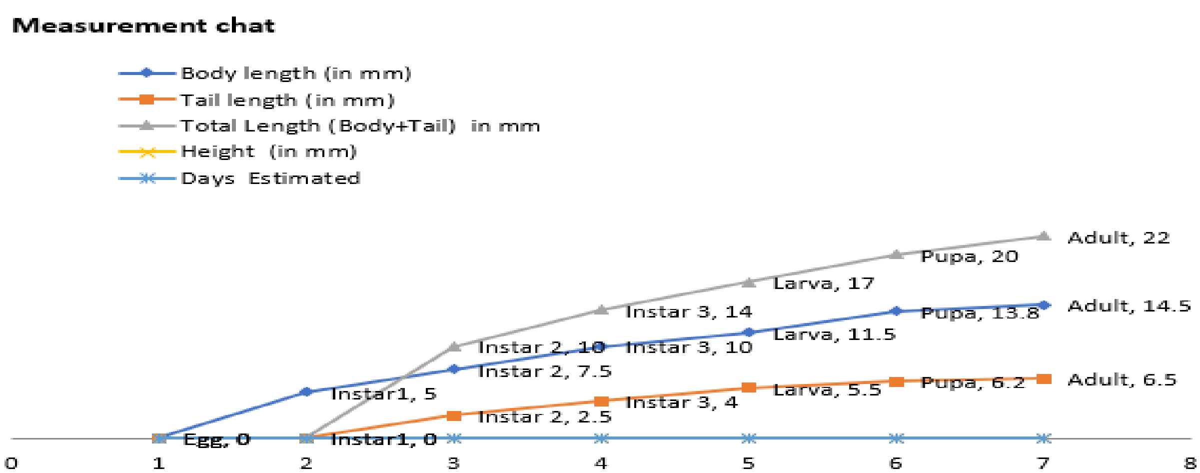


Figure 7. Image measurement in length of mm



m

Figure 8. Maggot measurement in length of mm

Here, resulting data is in digitized form, for automation of analysis approaches, by allowing collection of huge data-sets, the only problem remains is camera calibrations and the synchronization of images[11]. As details in the figure 8 shows the approach taken to follow is simple method for obtaining 3-Dimensional data of high quality from freely wandering insects with the aid of single high-resolution camera as illustrated in figure 9. This is collaborated with photo-automation analysis using software tracking, calibration and measurement methods [12]. In addition, the next approach followed describes a experiment by digitalizing images with novel algorithms of digital image processing [13]. Figure 10 and Figure 11 shows the Maggot covered pixel area Calculation is taken place, both of these pixels of maggot occupied region and known object region are calculated [8].

This paper known object is 2cm × 2cm square in length. So actual area of square object is 4 cm. Now insect occupied area is calculated using the formula, $Al = Pl\ Ps \times As$ (4) Where As is area of square covered under the maggot, which is 4cm2 . Ps is obtained by summing number of pixels in square object and Pl is obtained by summing number of pixels in insect region .At last area ( ) is calculated using with the above taken method. Finally error percentage is calculated as figure 12 , figure 13 and figure 14 shows.$Error\ Percentage = Ag - Al\ Ag \times 100\%$.

4. Experimental results

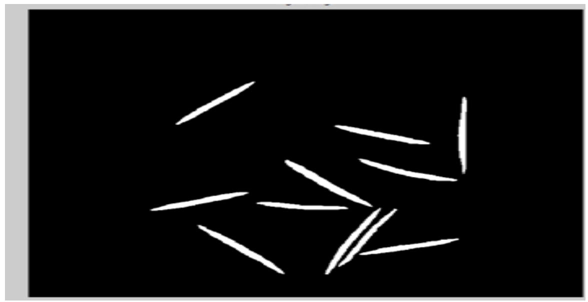


Figure 9. Captured insects

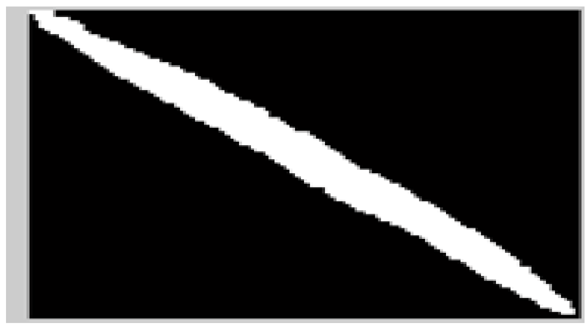


Figure 10 . Single insect placed for orientation for measurement which is alive was placed on a

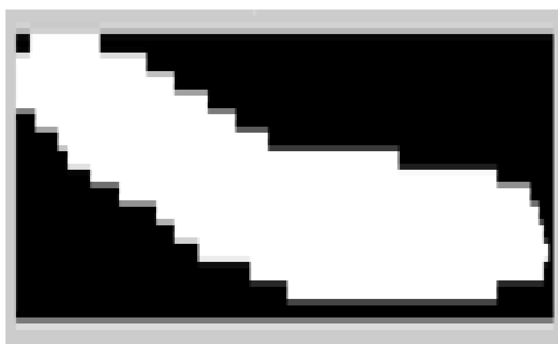


Figure 11. Maggot (larva)

Figure 12. GUI based input screen displaying different images captured

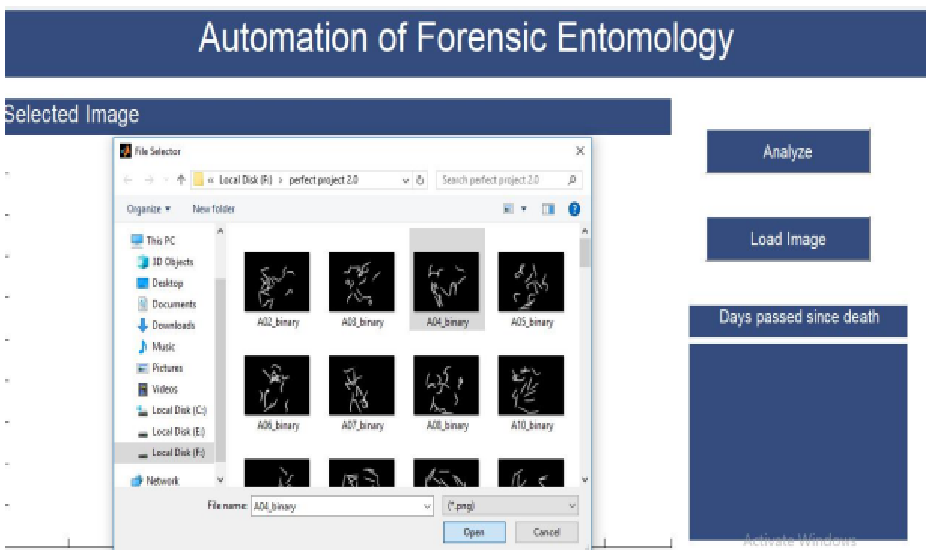


Figure 13. Selection of specific image to be processed

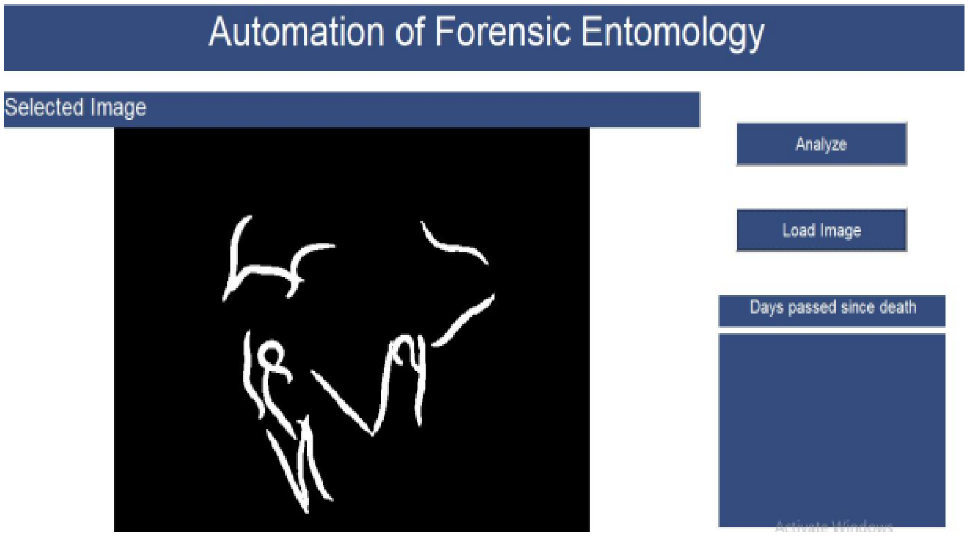


Figure 14. Output screen showing the number of days the death that has been taken (3 days)

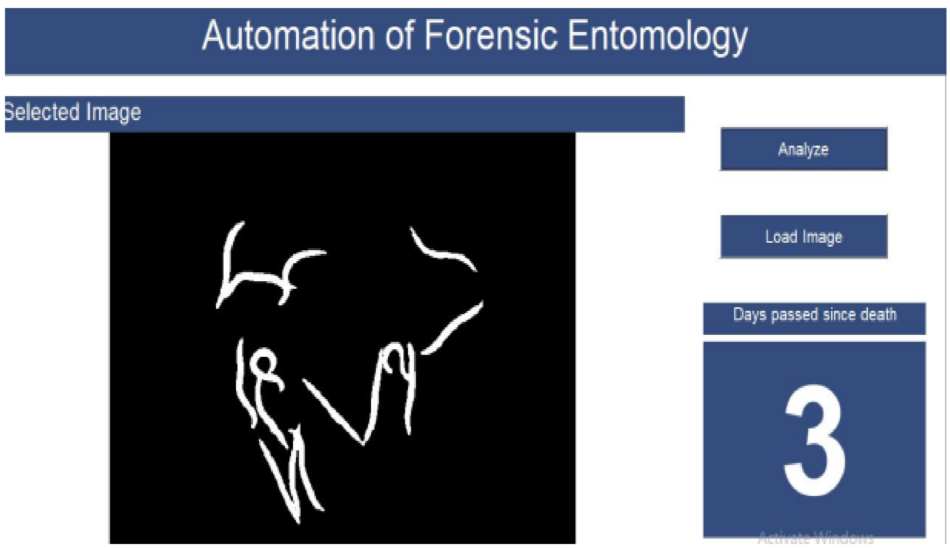


Figure 15. Image with the result day of death=3

5. Conclusion

Experiments were carried upon 40 dead bodies from different angles and the insects residing the dead body. Experimental results describe how this method was used to get insect area is measured. When we observed the Average accuracy rate of this algorithm is above 99% which is a desired output. Comparatively the results with measurements of grid count method are fruitful in nature. In future this method is needed to integrate both results and actual prediction of death yielding accurate results of investigation. Forensic entomology is an auspicious level of Forensic Science gives the scientific results within seconds of time if the special equipment and facilities inculcated. In this area of research, we mainly kept the efforts for the calculation of post-mortem interval, this efforts are not gone waste to make the comfortable applications for legal purpose, future investigation endeavours, and be prepared results with more accuracy.

Abbreviations

Conflicts of Interest

"The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

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Ethics Statement

"All entomological data and digital images used in this study were obtained following standard forensic protocols. No human or live vertebrate animal subjects were directly harmed or experimented upon for the purpose of this algorithmic validation. All data handling complied with the ethical guidelines of the participating institutional research committees.

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