Songklanakarin J. Sci. Technol.
32 (2), 169-173, Mar. - Apr. 2010

Songklanakarin Journal
of Science and Technology
http://www.sjst.psu.ac.th

*Original Article*

# Impact angle analysis of bloodstains using a simple image processing technique

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Received 3 Obtober 2009; Accepted 13 February 2010

**Abstract**

A simple method for blood spatter analysis was implemented using an image processing technique. The advantages of the computer application were exploited which subsequently provides minimal time consumed and user friendly interface. The outputs from the program associated with the string method are used for finding the origin of the incident, i.e. where the blood came from. The direction and the impact angle of the bloodstain use 4-step process analysis. The comparisons between outputs from the program and the traditional method were reported. The primitive outputs from the program are marginally acceptable with approximately 10% error; however, with a simple tweak manually, the errors drop more than three times.

**Keywords:** bloodstain pattern analysis, image processing, automatic process.

## 1. Introduction

One of the important evidences in a crime scene is the bloodstain, which gives vital information about the incident, i.e. where the incident occurred. The stains of blood droplets provide the direction from the origin and an advantage of the bloodstains analysis is that the method for calculating the impact angle is the same regardless of the force acting upon the blood source (Eckert *et al.*, 1999). The shapes of the stains vary from circle to oval depending on the impact angles from 90° to less than 90°.

The oval shape of a blood droplet provides two useful data, which are the glancing, or major axis angle ($\gamma$), and the impact angle ($\alpha$). The earlier angle is the angle of the bloodstain path measured from the true vertical of the surface (see Figure 1), while the later is the impact angle of the bloodstain path moving out from the surface (see Figure 2). These angles from several blood spots together with the basic method for blood spatter analysis, so-called "string method" provide crucial information, i.e. where the blood came from; hence, the origin of the incident. The name of this method comes from the way to analyze the bloodstains. The analyst attaches strings at the leading edges of the bloodstains and then pulls them away from the surface according to the angles discussed above and the origin of the blood is simply where these strings intersected or, in many realistic cases, almost intersected. One might also use another method such as tangent method for the same purpose where the flight path of a blood droplet is assumed to be the hypotenuse of a right triangle.

The bloodstain from the impact of blood droplets on a surface is caused by inertia. When a blood droplet collides on a surface, the inertia keeps the mass moving along the same path creating an elliptical or circular stain depending on the angle of impact. The shape of the bloodstain has both a major and minor axis unless, of course, impacting at 90°.

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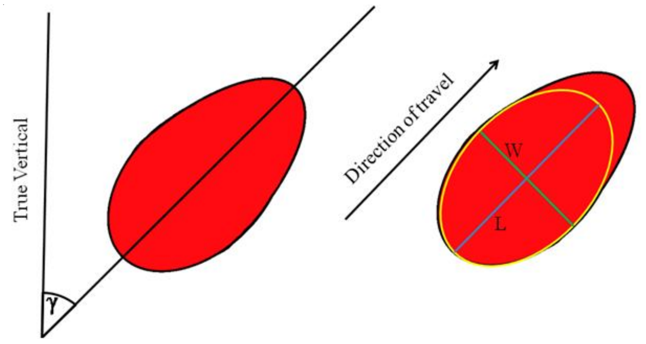



Figure 1. Bloodstain and the direction at less than 90° impact angle.

The major axis is always aligned with the path of the droplet (Bevel *et al.*, 2002).

From the minor and major axes, W and L refer to the width and length of the elliptical bloodstain, respectively. These data give the impact angle ($\alpha$) of the bloodstain. It was mentioned in Bevel *et al.* (2002) that Balthazard has recognized the relationship between length and width of the stain and the angle at which the droplet impacts and later MacDonell refined this idea by applying the length-width ratio with a sine function. The analysis was then to use a straight-line geometry technique in defining the bloodstain. From Figure 2, the width of the droplet can be considered as equal to line AB (the length) of the sphere. An analogy can then be drawn between line c and b and the width and length of the stain. Base on the analogy, line c and b are represented by line W and L of the stain, respectively. The impact angle calculation can be formulated as shown in Equation 1.

$$\alpha = \arcsin\left(\frac{W}{L}\right) \tag{1}$$

Commercial software, BackTrack™, has been developed to compute both Equation 1, thus $\alpha$, and the angle of the major axis $\gamma$. After a user clicks points in a digital image

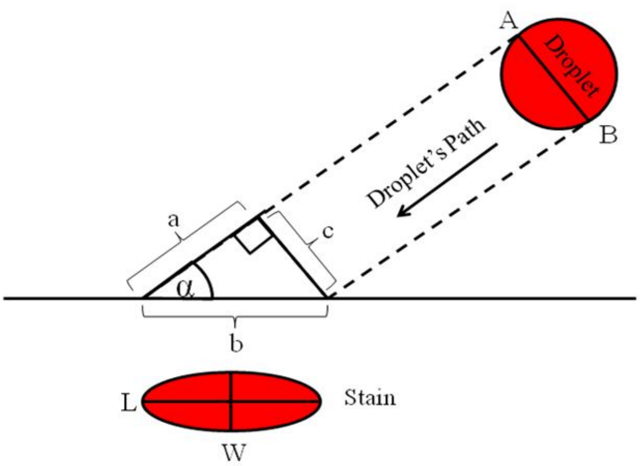



Figure 2. Schematic image of the bloodstain from a blood droplet with an impact angle ($\alpha$).

the software allows the angles to be stored and used to graph virtual strings (Carter *et al.*, 2001, 2006). Later, there was an attempt to visualize the string method by using computer-aided design (CAD) with BackTrack™ (Pace *et al.*, 2006). However, the user still has to manually find and outline the bloodstains. Another attempt was to develop an automatic process (Shen *et al.*, 2006). However, the error is relatively high and the algorithm is rather complex.

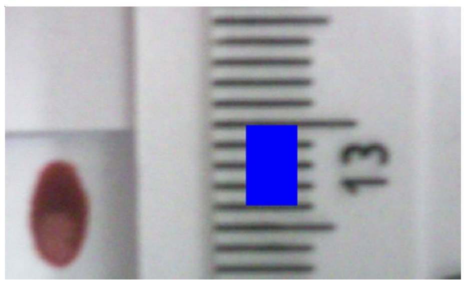
Our objective is to simplify the calculations of the impact and major axis angles for inexperienced or even experienced users using a simple image processing algorithm. The application also provides an option to the user when tweaking is required where the accuracy from the automatic process is not acceptable.

## 2. Image Processing

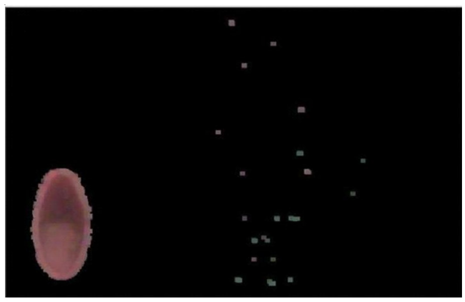
After, the bloodstain was digitally photographed with a marker - a color tab for converting pixels to actual distance - perpendicular to the ground; four analytical steps are required for the calculation.

### 2.1 Blood color identification

Blood color identification is the process which has to be executed after uploading the image to the program. Figure 3(a) shows an example of the image. The preset values in the program were used to identify the blood in the image. Figure 3(b) shows the image of blood after filtering out other colors. All the colors except blood color were then marked black.

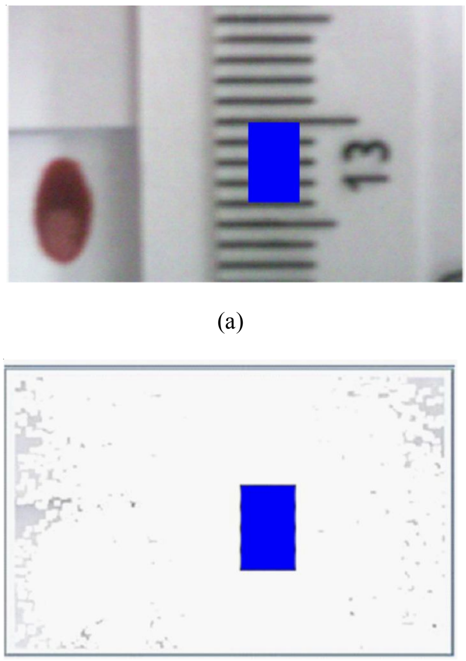



(a)



(b)

Figure 3. Image before (a) and after (b) the blood color identification process.



(a) (b)

Figure 4. Image before (a) and after (b) the finding marker process.

## 2.2 Marker identification

The marker, which is a piece of a known-size rectangular, was attached nearby the bloodstain. The marker assists the program to rectify the dimension. It is always affixed perpendicular to the ground, as shown in Figure 4(a). There are two colors on the markers, green and blue. Only one color is used at a time according to the color of the surface. From the original image, the program locates the marker by selecting the color of the marker and sets the rest of the image to white. The remaining color, i.e. marker, was then measured for the size and converted into the dimensions of W and L from pixels to millimeters.

## 2.3 Major axis angle (γ) calculation

After the process of blood color identification and the correction with the information from the marker, the image, which was left with the bloodstain, was fit with a rectangle as shown in Figure 5.

The program tries to fit the bloodstain with a rectangle where the corners are marked with A, B, C, and D as show in Figure 5. The corner points, A, B, C, and D, are to provide the distances of the sides of the rectangle, ΔX and ΔY. The major axis angle (γ) was calculated using Equation 2.

$$\gamma = 90 - \arctan(\frac{\Delta Y}{\Delta X}) \quad (2)$$

The γ given from Equation 2 represents two possibilities as shown in Figure 6. In order to determine the direction of the bloodstain, the image has to be separated into four quadrants. The covered areas in the quadrants are to be used for the determination of the two possibilities. If the areas in $Q_1$ and $Q_3$ are less than the areas in $Q_2$ and $Q_4$, the bloodstain shown in Figure 7(a) is the result; otherwise Figure 7(b) is showing the result.

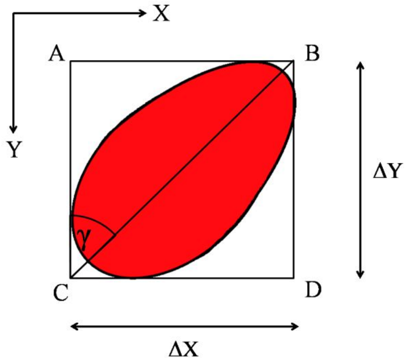



Figure 5. Isolated bloodstain with the rectangle fitting of the bloodstain.

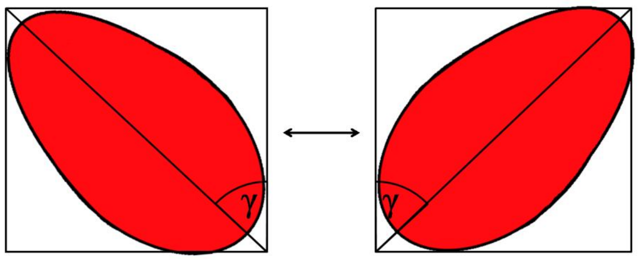
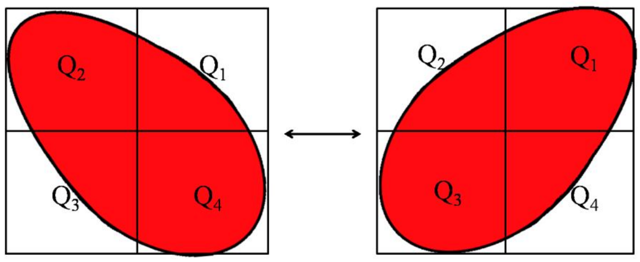



Figure 6. bloodstains with the same angle but different directions.

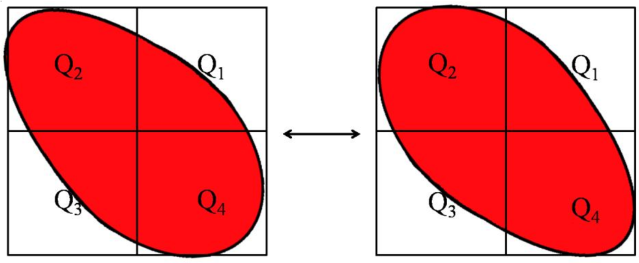



(a) (b)

Figure 7. Images of bloodstains shown in four quadrants.

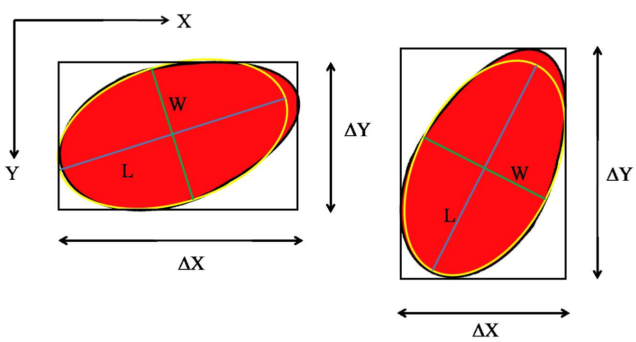
Once the solution was found, the other question arises. If Figure 7(a) is the solution, there are another two possibilities to be considered as shown in Figure 8(a) and (b). The blood drop could be traveling from Q4 to Q2 or the other way round. In order to rectify the solution, both areas in Q2 and Q4 are to be compared. Figure 8(a) has the area of Q4 greater than Q2 and vice versa.

Once the program shows the result from its automatic process, the user could manually tweak the γ angle to correct




(a) (b)

Figure 8. Two possibilities of the blood drop traveling from different directions.




(a) (b)

Figure 9. Ellipses fitted on the two possibilities of bloodstains.

the results, if one suspected the incorrect answer. This might come from a systematic error or from the case where the shape of the droplet is rather symmetric.

### 2.4 Impact angle calculation

Prior to the calculation of α, W and L have to be determined. Again, two possibilities exist as shown in Figure 9. The W and L from Figure 9(a) and (b) can be calculated by Equation 3 to 6 where Equation3 and 4 are for Figure 9(a) and Equation 5 and 6 are for Figure 9(b).

$$W \approx \Delta Y \bullet \left[\frac{\Delta Y}{\Delta X}\right] \tag{3}$$

$$L \approx \sqrt{\Delta X^2 + \Delta Y^2} \tag{4}$$

$$W \approx \Delta X \bullet \left[\frac{\Delta X}{\Delta Y}\right] \tag{5}$$

$$L \approx \sqrt{\Delta X^2 + \Delta Y^2} \tag{6}$$

As well as γ, W and L could be manually adjusted if required. W and L are calculated in pixel units, with a calibration required to convert pixel length into actual length using the known size of the marker (2×4 $mm^2$) as mentioned earlier. Finally, α could be calculated using Equation 1.

## 3. Program verification

Tests were performed on thirty bloodstain droplets created from a weight drop on 100 ml pool of blood. Table 1 shows the average %-error of W, L, α, and γ from the automatic calculations compared with the manual adjusting for

Table 1. Comparisons of average %-error of calculated parameters between automatic calculation and manual adjusting for best fit of the parameters.

| Parameters | Average %-error | | | |
|---|---|---|---|---|
| | Automatic | | Manual | |
| | Blue | Green | Blue | Green |
| Width, W (mm) | 11.84 | 13.31 | 2.22 | 2.98 |
| Length, L (mm) | 6.24 | 9.62 | 1.63 | 1.78 |
| Impact angle, α (deg) | 12.47 | 11.86 | 3.70 | 3.36 |
| Major axis angle, γ (deg) | 10.81 | 10.81 | 0.93 | 0.98 |

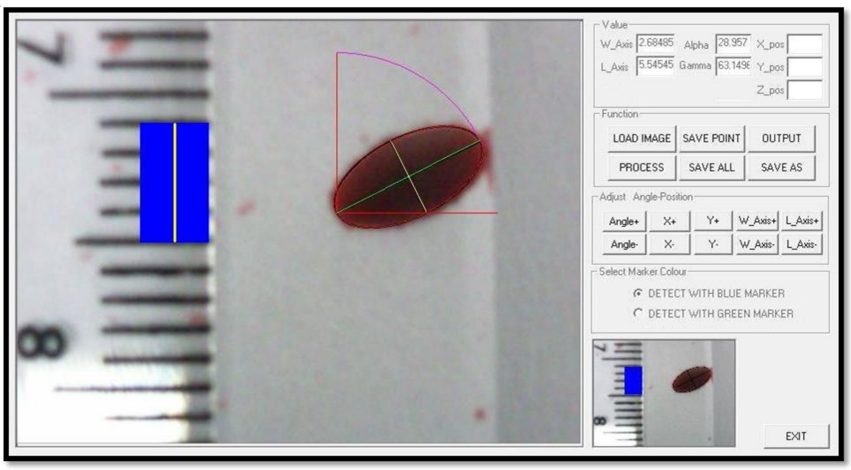



Figure 10. Screenshot of the application during the process.

best fit of the parameters. Two markers were used and compared. The %-error was calculated form Equation 7.

$$\%\text{error} = \frac{\text{Value}_{\text{actual}} - \text{Value}_{\text{program}}}{\text{Value}_{\text{actual}}} \times 100 \qquad (7)$$

Figure 10 illustrates the screenshot of the program. After uploading an image of blood droplets with a marker and input the color of the maker to the program, it automatically fits the best ellipse of the droplet and gives the results of W, L, $\alpha$ and $\gamma$. All the lengths data in the program will be reported in millimeters. A user could tweak the results for more accurate results if required.

## 4. Discussion

The results from a simple image processing technique using thirty bloodstains on white background indicated that average %-error of all parameters with an automatic processing is marginally acceptable. However, the overall results of W, L, $\alpha$ and $\gamma$ from the manual process showed better results. Therefore, the manual process is required if there is a concern for more accurate results.

## 5. Conclusion

This work developed a simple image processing method for rapid and non-biased bloodstain pattern analysis. From the results, the automatic process is acceptable. However, if the average %-error is still unacceptable in any case, the user has an option for tweaking the results manually. Different markers are used when the background might cause confusion to the automatic processing in the program.

## Acknowledgements

K.B. would like to express his gratitude to the Faculty of Science, Prince of Songkla University for his research assistantship during his study at the Forensic Science Program. P.A. would like to thank ESR, New Zealand, especially Dr. M. Taylor for his inspiration and Faculty of Science, Prince of Songkla University for a visiting grant to New Zealand.

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