Errors in Blood Droplet Impact Angle Reconstruction Using a Protractor

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Bloodstain patterns lend themselves to geometric interpretation whereby it is possible to determine relative impact angles and areas of origin [1]. Through precise measurement and documentation, bloodstain evidence can support or negate witness testimony, and reconstruct the events of a crime. In the final analysis, bloodstain evidence can be the deciding factor in solving the major criminal investigation.

The current method used to reconstruct bloodstain evidence at the crime scene is known as the string method. The string method is a procedure in which individual pieces of string are used to reconstruct the blood droplet’s flight path, impact angle, and area(s) of origin [2]. This is accomplished by running the string from the points at which the blood droplets impacted to a pre-calculated impact angle converging at the area(s) of origin. It is often a time-consuming and cumbersome process, especially if the crime scene contains a multitude of blood droplets and stains patterns. Generally two persons are needed to properly bloodstain evidence using the string method. One person is needed to hold the end of the string at the blood droplet’s point of impact, while the second person is needed to readjust the string at the area of origin. This procedure may be repeated as many times as there are significant blood droplets, and given a bloody crime scene it can take a very long time to complete. The tool most frequently used by the Crime Scene or Evidence Technicians to manually measure blood droplet impact angles is the universal protractor. Although the protractor is the universal tool used to measure angles.

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in two-dimensional space, it’s degree of accuracy becomes compromised when it is used to measure angles in three-dimensional space. The standard protractor (Figure 1) is designed such that degrees are measured in two-dimensional space only. It is made to be placed flat on a piece of paper and the angle is drawn using the vertex as the (0, 0) coordinate. However, when the protractor is used to measure the degree of a blood droplet’s impact angle at a crease, i.e., in a three-dimensional space, the degree of accuracy is decreased because it’s physical design. Most protractors are constructed with a spine that connects the base line and the vertex (the point from which the angle is measured). Although this space may appear to have little significance as the length of this space increases, it does the displacement of the blood droplet’s calculated impact angle and consequently it’s area of origin. In Figure 1, a standard protractor is shown with a space of 2.5 inches (3 cm) between the vertex and the base line. In Figure 2, the same protractor is used below a twenty degree blood droplet impact angle to measure the two dimensions. As the vertex is positioned over the blood droplet’s point of impact (the protractor is placed perpendicular to the surface), the 20° measurement is in error by approximately 4.3%. The actual angle measured is 24.35°. The area of origin is therefore displaced by a distance “a.” See Table 1 for the area of origin displacement distance “a” in inches at 20°. In order to calculate the margin of error in degrees, angle 4, and the area of origin displacement distance, length “a,” basic trigonometry is used.

In Figure 1, triangles a, b, c and triangle a°, b°, c° represent triangles containing the calculated impact angle and actual angle measured, as illustrated in Figure 2, respectively. Angle 4° angle b° represent the calculated impact angle and actual angle measured respectively. Since both 0° and 0° are angles within right triangles, and given that distance 0° equals b°, the actual angle measured, b°, is calculated using the laws of sines and the laws of cosines. (1) The laws of sines and the laws of cosines are ratios derived from the trigonometric functions that can be used to solve right triangles.

Referring to Figures 1 the trigonometric formulas are the following:

\[
\sin \theta \cdot \frac{a\cos \theta}{b} = \frac{b}{c} \quad \cos \theta = \frac{a}{b} \quad \tan \theta = \frac{c}{b}
\]

Example

Let 0° = 20°, where 0° is a blood droplet’s calculated impact angle. Let c = 3 inches, where c is the radius of the protractor from the vertex. Calculate b°, the actual angle measured.

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Fig. 1. Standard protractor with a 1° space between vices and baseline.

Fig. 2. Angle A illustrates the margin of error between the angles measured from the vertex and the baseline.

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Fig. 5. Triangles formed with separate values for $\theta$ and $\theta'$ usingprotractor in Fig. 2.

Solution

From the trigonomic formula $\sin \theta = \frac{a}{c}$ the following equation is arrived:

$$\sin \theta = \frac{b}{c}$$

$$a = (\sin \theta) \cdot c$$

$$a = (0.5877853) \cdot c$$

$$a = 1.6260043$$

Using the Pythagorian Theorem, $a^2 + b^2 = c^2$, the value for $b$ is solved with the following equation:

$$(1.6260043)^2 + b^2 = c^2$$

$$b = \sqrt{c^2 - (1.6260043)^2}$$

$$b = 2.80797662$$

The value for $\theta'$ can now be solved with the following equation:

$$\tan \theta' = \frac{a}{b}$$

$$\tan \theta' = \frac{1.6260043}{2.80797662}$$

It is given that $b = \beta'$. Therefore the final equation is the following:

$$J. F. Kosanic-Jones,
42(1), 1991-93$$
In the Table, the blood droplet impact angle $\theta$ is given in increments of five degrees. The actual angle measured is calculated by the above method, and the margin of error obtained by subtracting the impact angle from the actual angle measured. Therefore, the margin of error for the above problem is calculated by the following equation:

$\theta = 45.35\degree - 20\degree = 25.35\degree$

The area of sight: The displacement distance $d$ has been calculated in increments of fifty inches from the twenty degree instruction point on the prints. In order to solve for distance $d$, the following trigonometric formula is used:

$d^2 = b^2 + c^2 - 2bc \cos A$

Example

Calculate the displacement distance $d$ in which the impact angle, $B$ is 20° and the area of origin is determined to be 150° from the twenty degree instruction point on the prints. Where 150° equals distance $b$ equals distance $c$ (i.e., 150° = b = c).

Solution

From the previous example, the value for angle $A$ equals 45.35°. By placing the values for $h, c$, and $A$ into the above equation, the value for the displacement distance $d$ is solved:

$d = \sqrt{(150^2 + (150)^2 - 2(150)(150)\cos 45.35°)}$

$s = 11,385,53843$

$s = 11.39\, \text{in}$

Conclusion

At first crime sites involving bloodstain evidence it may generally suffice to render an educated estimate of the blood droplet's impact angle and area of origin. However, when the nature of the investigation demands that the impact angles must be precisely measured and area of origin accurately reconstructed, a more precise method may be necessary.
the utilization of a protractor that has the capability to measure angles in three-dimensional space is performed. Figure 4 illustrates a protractor whose vertex and the base line lie on the same axis, thereby securing the protractor of choice.

An alternative procedure for measuring blood droplet impact angles, that

Fig. 4. Protractor in which vertex and base line lie on same axis.

Fig. 5. The string is positioned through the protractor's vertex and onto the base line, at the blood droplet's impact point, such that angle $\alpha$ and angle $\beta$ equal.

corresponding for the space between the protractor's vertex and base line, $\beta$-type

3. Howard Stern
42(1), 1991, 31
by extending the string through the nose and onto the base line at the hood center’s impact point. See Figure 6. This procedure will eliminate the displacement distance "a," and thereby result in a more accurate and reliable crime scene reconstruction.

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