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 paths, impact angles, and area(s) of origin.[2] This is accomplished by running the strings from the points at which the blood droplets impacted to a pre-calculated directional 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 strike patterns. Generally two persons are needed to process bloodstain evidence using the string method. One person is needed to hold one end of the string at the blood droplet's point of impact, while a second person is needed to extend the other end of the string to 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 Technician to manually measure blood droplet impact angles is the standard 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 degrees of a blood droplet's impact angle at a crime scene, i.e. in a three-dimensional space, the degree of accuracy is dependant upon it's physical design. Most protractors are constructed with a space that separates the base line and the vertex (the vertex is the point from which the angle is measured). Although this space may appear to have little significance, as the length of this space increases, so 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 .25 inches (¼") between the vertex and the base line. In Figure 2, the same protractor is used to draw a twenty degree blood droplet impact angle that is measured in three 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 4.35°. The actual angle measured is 24.35°. The area of origin is therefore displaced by a distance "a." See Table I for the area of origin displacement distance "a" in inches at 20°. In order to calculate the margin of error in degrees, angle A, and the area of origin displacement distance, length "a," basic trigonometry is used.

In Figure 3, triangle a, b, c and triangle a^1, b^1, c^1 represent triangles containing the calculated impact angle and actual angle measured, as illustrated in Figure 2, respectively. Angle θ angle θ^1 represent the calculated impact angle and actual angle measured respectively. Since both θ and θ^1 are angles within right triangles, and given that distance b equals b^1, the actual angle measured, θ^1, is calculated using the laws of sines and the laws of cosines.[3] The laws of sines and the laws of cosines are ratios derived from the trigonometric functions that can be used to solve all triangles.

Referring to Figure 3 the trigonometric formulas are the following:

$$\sin\theta = \frac{a}{c} \qquad \cos\theta = \frac{b}{c} \qquad \tan\theta = \frac{a}{b}$$

and:

$$\sin\theta^1 = \frac{a^1}{b^1} \qquad \cos\theta = \frac{b^1}{c^1} \qquad \tan\theta = \frac{a^1}{b^1}$$

Example

Let $\theta = 20°$, where θ is a blood droplet's calculated impact angle. Let $c = 3$ inches, where c is the radius of the protractor from the vertex. Calculate θ^1, the actual angle measured.

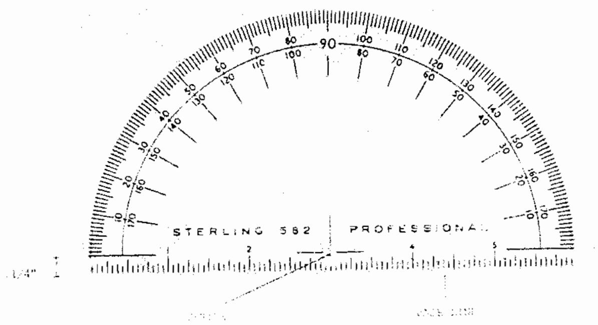

Fig. 1. Standard protractor with a ¼" space between vertex and base line.

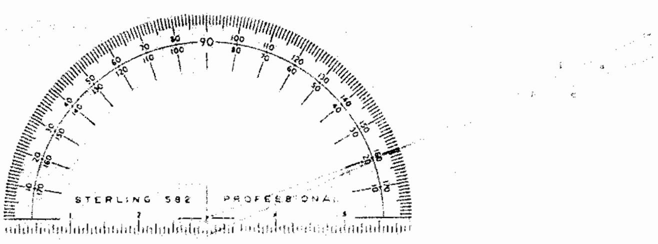

Fig. 2. Angle A illustrates the margin of error between the angles measured from the vertex and the base line.

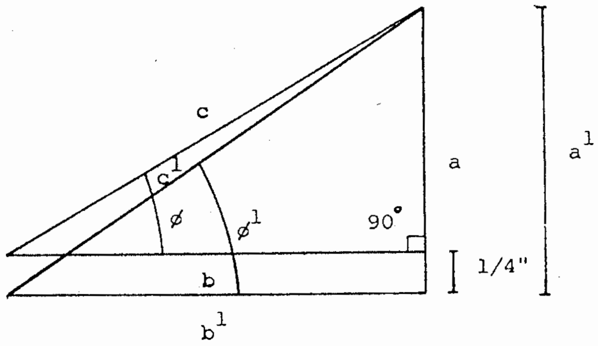

Fig. 3. Triangles formed with separate values for θ and θ[1] using protractor in Fig. 2.

Solution

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

$$\sin 20^\circ = \frac{a}{3}$$

$$a = (\sin 20^\circ)(3)$$

$$a = (.342020143)(3)$$

$$a = 1.02606043$$

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

$$(1.02606043)^2 + b^2 = (3)^2$$

$$b = \sqrt{9 - 1.052800006}$$

$$b = 2.819077862$$

The value for θ^1 can now be solved with the following equation:

$$\tan \theta^1 = \frac{a^1}{b^1} \quad \text{where} \quad \tan \theta^1 = \frac{a + .25}{b^1}$$

It is given that $b = b^1$. Therefore the final equation is the following:

$$\tan \theta^1 = \frac{1.02606043 + .25}{2.819077862}$$

$$\tan \theta^1 = .452651715$$

$$\theta^1 = 24.35396672$$

$$\theta^1 = 24.35°$$

In the Table the blood droplet impact angles are given in increments of five degrees. The actual angle measured is calculated by the above method, and the margin of error is 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:

$$\theta^1 - \theta = \text{Margin of Error in Degrees}$$

where,

$$24.35° - 20° = 4.35°$$

The area of origin displacement distance "a" has been calculated at increments of fifty inches from the twenty degree intersection point on the protractor. In order to solve for distance "a" the following trigonometric formula is used:

$$a^2 = b^2 + c^2 - 2bc\,(\cos A)$$

Example

Calculate the displacement distance "a" in which the impact angle, θ is 20° and the area of origin is determined to be 150" from the twenty degree intersection point on the protractor, where 150" equals distance b equals distance c (i.e., 150" = b = c).

Solution

From the previous example the value for angle A equals 4.35°. By placing the values for b, c, and A into the above equation, the value for the displacement distance "a" is solved.

$$a^2 = (150)^2 + (150)^2 - 2(150)(150)(\cos 4.35)$$
$$a = 11.38553843$$
$$a = 11.39"$$

Conclusion

At most crime scenes 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, the utilization of a protractor that has the capability to measure angles in three dimensional space is preferred. Figure 4 illustrates a protractor where the vertex and the base line lie on the same axis, thereby making it the protractor of choice.

An alternative procedure for measuring blood droplet impact angles, that

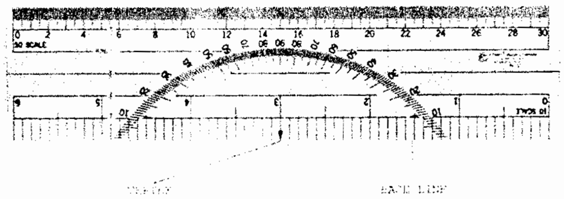

Fig. 4. Protractor in which vertex and base line lie on same axis.

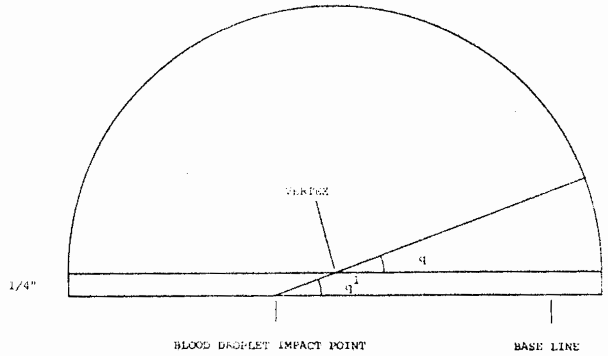

Fig. 5. The string is positioned through the protractor's vertex and onto the base line, at the blood droplet's impact point, such that angle q and angle q^1 equal.

compensates for the space between the protractor's vertex and base line, is done by extending the string through the vertex and onto the base line at the blood droplet's impact point. See Figure 5. This procedure will eliminate the displacement distance "a," and thereby result in a more accurate and credible crime scene reconstruction.

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References:

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2 MacDonell, H.L, Fiske Bialouse, L., *"Flight Characteristics and Stain Patterns of Human Blood,"* NILE CJ, 1971, p 24.

3 Bunker, J.L., *"Bloodstain Evidence Workshop I,"* J.L. Bunker & Assoc., 1989, pp 6-7.