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BLOODSTAIN PATTERN ANALYSIS WITH A SCIENTIFIC CALCULATOR

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ABSTRACT

A procedure is described for calculating the horizontal position (X,Y coordinates) of the point of convergence for the paths of a pair of blood droplets selected from a bloodstain pattern. Both fast upward moving droplets and the slower downward moving droplets can be utilized. The latter stains, which are excluded from the string method, can be included in this method because no attempt is made to determine the vertical position of the point of convergence.

The procedure is a fast reliable technique for locating preliminary convergence points without using the cumbersome string method. The calculation is straight forward and can easily be done at the scene of the crime. Accuracy is mainly limited by the estimates of the incidence angles of the two stains. These estimates are determined from the shape of the droplet stains in the usual manner.

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INTRODUCTION

Bloodstain pattern analysis can yield valuable evidence for the reconstruction of events at the scene of a crime.[1,2,3] Precise measurements of the position and the two impact angles of individual droplet stains can be interpreted and understood by applying the Laws of Physics governing projectile motion. The following is a discussion of the physical and mathematical properties of the flight of blood droplets with applications to bloodstain pattern analysis.

DISCUSSION OF THE PHYSICS

After the formation of a particular blood droplet at a specific point in space, regardless of the physical event that caused the formation, the path of that droplet through still air is determined by the values of four numbers or parameters unique to that droplet. These four parameters are, the diameter of the drop, the initial speed of the drop and the two angles which are necessary[3] to specify the initial direction of motion of the droplet. Some information regarding the diameter of the drop can be inferred from the size of the stain produced by the droplet. However, the initial speed and direction are unknown quantities and can only be estimated by analysis.

3. In three dimensions, two angles are required to describe a direction in space, e.g. (1) the compass bearing from north, 0 to 360 degrees and (2) the elevation, 0 to 90 degrees.

The subsequent motion of the droplet is influenced by two forces.[4] The first is the force of gravity which acts on the droplet by pulling it downward with a constant force as it moves through the air. The second force is due to the viscosity of air and comes into play when any object moves through the air. Both forces depend on the size of the droplets but in a different way. The force of gravity increases with the size of the droplet but is constant for a given droplet. The force of air resistance increases also, with the size of the droplet but its effect on the path actually decreases with the increase in droplet size. This force differs from that of gravity by its dependence on the speed of the droplet, it increases with the square of the speed.

The directions of the two forces have different properties as well. The direction of the force of gravity is downward and does not change its direction. The direction of the force of air resistance is exactly opposite to the direction of the droplets motion, therefore it is changing its direction continuously as the droplet moves along its curved path.

If gravity were the only force acting on the droplet, or if the air resistance could be neglected, then the path of the droplet would be a perfect parabola. However, in most instances, the blood stains of interest result from droplets in the microliter range, and the air resistance cannot be neglected. The shape of the path for such droplets can deviate substantially from a simple parabola.

Therefore the vertical movement of the droplets during their flight will be influenced by air resistance according to the individual sizes of the droplets and their initial speeds. The calculations of the vertical profiles of the droplets require estimates of their individual sizes and speeds. These calculations are only practical with a computer because they are complex and time consuming. A subsequent paper will describe a more complete procedure for bloodstain analysis that utilizes size and speed estimates for each droplet. The procedure makes use of a microcomputer to calculate the paths of each droplet and it includes the effect of air resistance on the paths.

DISCUSSION OF THE MATHEMATICS

There is a mathematical limitation imposed on the complete reconstruction of the paths due to the fact that the speed of the droplets, at the moment of impact with the wall, is unknown and cannot be estimated with any degree of certainty. This limitation results in a lack of precise knowledge of the vertical position of the droplets while in flight except, of course, where they strike the walls or other surfaces. Therefore, without knowing the impact speed of the droplets, one cannot calculate the vertical coordinate of the point of convergence.

Fortunately there is no such limitation on the calculations for the horizontal position of the point of convergence. In principle, given the values of the location and impact angles of two droplet stains along with the horizontal separation of the two stains (labeled **D** in figure 1) one can calculate exactly, the horizontal position of the convergence point (labelled **P** in figure 1).

The method described in this paper, for locating the horizontal position of the convergence points, is independent of the speed of the droplets and therefore independent of air resistance as well. This simplification is achieved by projecting the paths of the various droplets on to a horizontal plane, and limiting the analysis to this projection, i.e. working with the "top view" of the paths. This approach has the advantage that all the paths appear as straight lines which cross each other at the probable convergence points. Since only straight lines are involved, the mathematics is reduced to basic trigonometry which can be done on any scientific calculator equipped with trigonometric functions.

Figure 1 shows the top view of two such paths depicted as dotted lines. They lead, from a pair of bloodstains separated by a distance **D** , to a convergence point **P**. The object of this paper is to describe how to calculate the position of **P** specified by the values of **X** and **Y**.

{ Figure 1 goes here}

THE TRIGONOMETRIC FORMULAS

Referring to figure 1, the directions of the paths of droplets with respect to the wall require the calculation of only two angles. Although any two droplet stains can be used, we choose a pair of stains that bracket the convergence point. This choice helps to reduce the systematic errors caused by the uncertainty in the W/L measurements (see equation 1). For the droplets shown, these angles are labeled beta left (β_L) and beta right (β_R). Also, the two coordinates of the convergence point are given by:

$$X = d * \sin(\beta_L) \qquad Y = d * \cos(\beta_L),$$

where **X** and **Y** are referred to the location of the left droplet for convenience, (i.e. the left droplet stain is located at **X** = 0 and **Y** = 0).The three quantities β_L, β_R and **d** are two angles and one side of a triangle which includes **D** as one of the other sides. The angle opposite **D** is equal to 180 - β_L - β_R degrees. Therefore using the law of sines;

$$d = D * \sin(\beta_R) / \sin(180 - \beta_L - \beta_R).$$

Thus, by substituting this expression for **d** in the two equations above the results are:

$$X = D * \sin(\beta_L) * \sin(\beta_R) / \sin(180 - \beta_L - \beta_R)$$

$$Y = D * \cos(\beta_L) * \sin(\beta_R) / \sin(180 - \beta_L - \beta_R)$$

or

$$Y = X * \cot(\beta_L).$$

It remains to calculate β_L and β_R.

These angles which are called ß in this work specify the directions of the paths as seen from the top view. Each droplet stain has a ß direction which depends on the two "angles of impact" of the stain. The latter angles are known as the impact angle alpha (α) and the glancing angle gamma (γ) and they are estimated from the shape of the stains on the walls.

The glancing angle gamma is the angle on vertical surfaces between the major axis of the stain and the vertical direction as determined with a plumb line. Figure 2 shows the convention used here for measuring the glancing angles γ_L and γ_R. This convention has been chosen so that the value of the sine of gamma remains positive for both droplets.

The impact angle alpha is determined from the ratio of the width (W) to the length (L) of the droplet stain according to the relation

$$\sin(\alpha) = W / L. \quad (1)$$

This empirical relationship has been discussed previously,[5,6] and its validity for this procedure has been verified by experiments carried out by the authors at the R.C.M.P. Central Forensic Laboratory in Ottawa. The results of these experiments were reported recently.[7]

{ Figure 2 goes here}

The relationships between the angles α, ß and γ are shown in figure 3. This figure depicts a bloodstain with a value of gamma equal to 45 degrees and is meant to represent the right droplet of a pair of droplets that are being analyzed. The velocity vector, **V**, represents the speed and direction of the droplet at the instant of impact. The three components of **V** are labeled $\mathbf{V_x}$, $\mathbf{V_y}$ and $\mathbf{V_z}$. From this diagram it can be seen that the angles satisfy the following equations,

$$\tan(\alpha_R) = V_x / \sqrt{(V_y^2 + V_z^2)},$$

$$\sin(\gamma_R) = V_y / \sqrt{(V_y^2 + V_z^2)},$$

$$\tan(\beta_R) = V_x / V_y.$$

Dividing the first and second equations and combining the result with the third yields

$$\tan(\beta_R) = \tan(\alpha_R) / \sin(\gamma_R). \qquad (2)$$

The latter equation enables the computation of the direction angle β_R from the two measured angles α_R and γ_R . A similar equation exists for the direction angle β_L. e.g.

$$\tan(\beta_L) = \tan(\alpha_L) / \sin(\gamma_L).$$

{ Figure 3 goes here}

PROCEDURE FOR COMPUTING THE VALUES OF X AND Y

From the bloodstain pattern one chooses two suitable droplet stains that are separated horizontally by a distance of approximately one meter, more or less depending on the circumstances. The two stains may be on the same or different walls or other vertical surfaces. They will, in general, be located at different heights, thus two plumb lines should be drawn at the positions of the stains to establish the vertical directions. The horizontal separation of these vertical lines is labeled **D** in figure 1. This distance is best measured with the aid of a level.

The glancing angle gamma (γ) is the angle that the major axis of the stain makes with the upward vertical direction. Clockwise rotation is used for the right droplet stains and counter clockwise for those on the left. (See figure 2.)

The impact angle alpha (α) is computed in the usual way from the estimated values of W and L, the width and length of the stain. Thus, the following are derived from equation (1):

$$\alpha = \arcsin (W / L),$$

and from equation (2):

$$\beta = \arctan (\tan (\alpha) / \sin (\gamma)).$$

The two droplet stains will yield values for β_L and β_R in this way and finally the position of the point of convergence is given by:

$$X = D * \sin (\beta_L) * \sin (\beta_R) / \sin (180 - \beta_L - \beta_R),$$

$$Y = D * \cos (\beta_L) * \sin (\beta_R) / \sin (180 - \beta_L - \beta_R).$$

CONCLUSION

We have described a procedure for finding the two horizontal coordinates of the point of convergence for a pair of droplet stains. This procedure does not require the impact velocities of the droplets and therefore is independent of air resistance. Calculations are kept to a minimum by using only two droplets at a time. The formulas are trigonometric equations easily solvable with a pocket calculator at the scene of the crime. The method should prove useful for preliminary analysis and for correlating droplet stains with possible convergence points.

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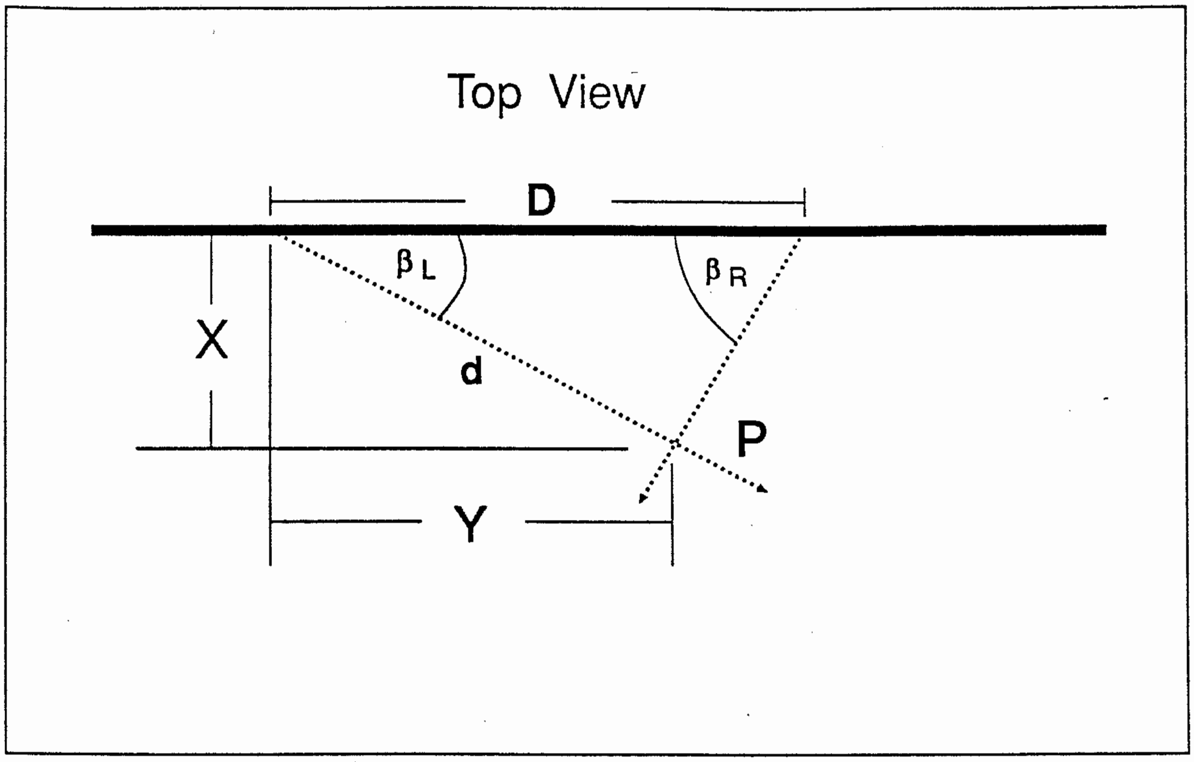

Figure 1. The top view showing the analysis of two droplet stains.

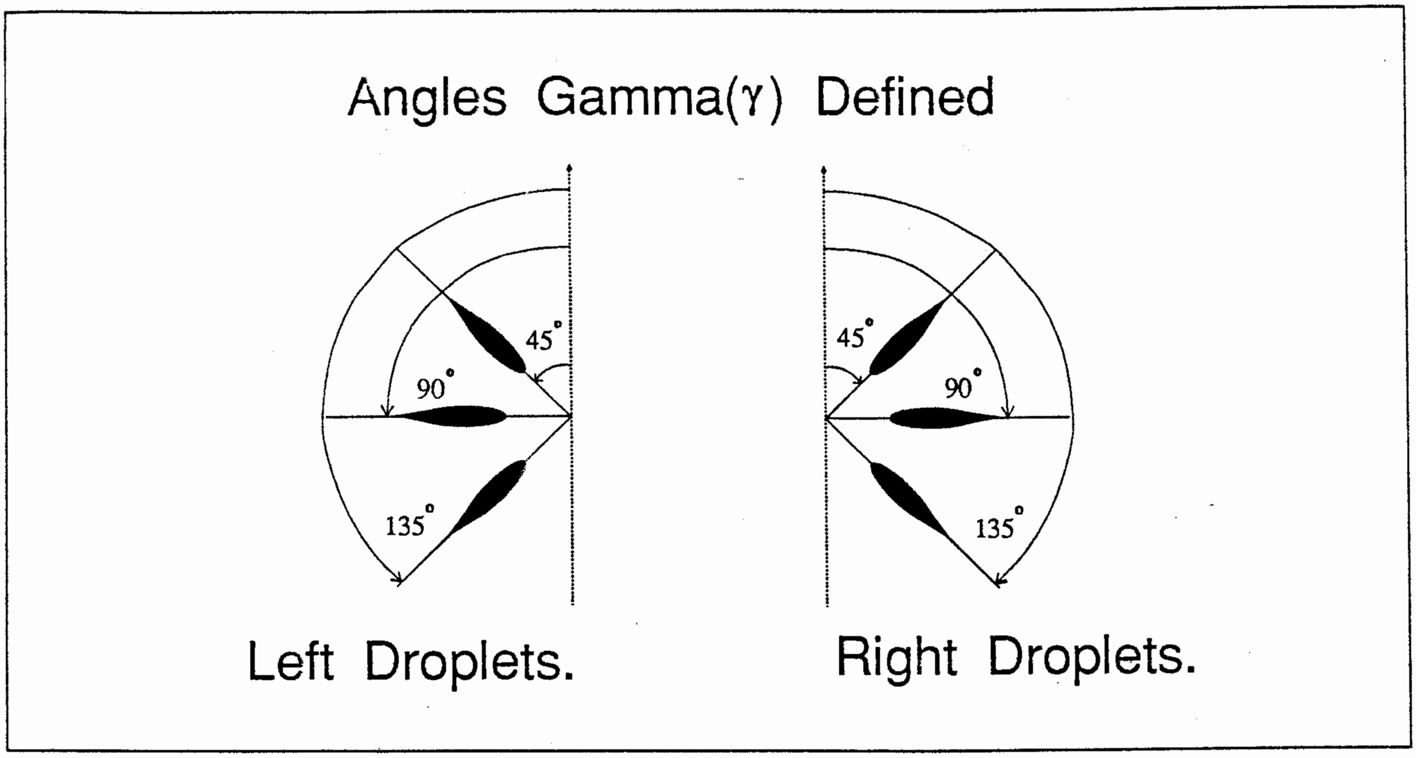

Figure 2. The convention for the glancing angles.

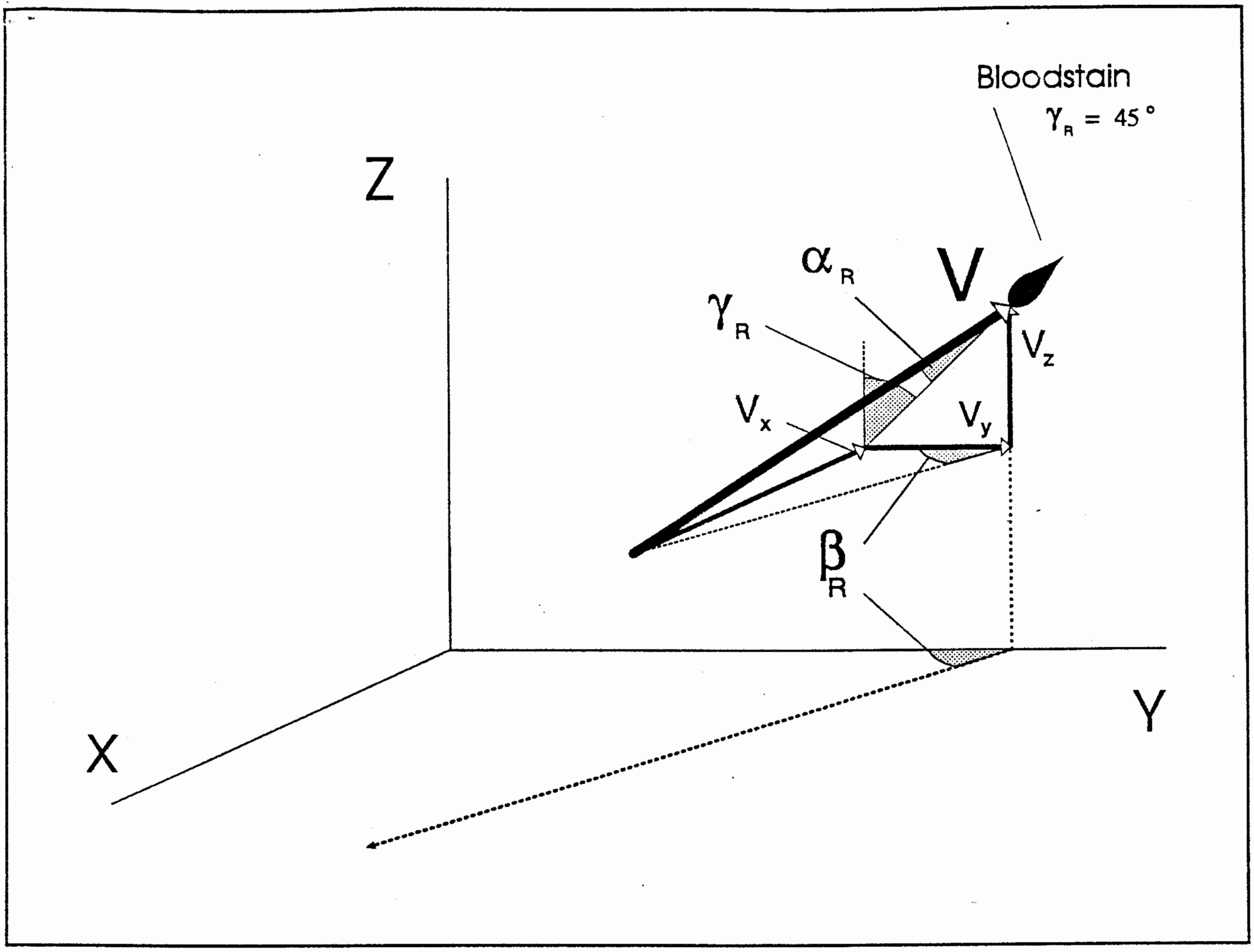

Figure 3. The impact velocity and its relationship to the impact angles.