RESEARCH ARTICLE

Further Validation of the BackTrack™ Computer Program for Bloodstain Pattern Analysis – *Precision and Accuracy*

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Abstract

The BackTrack™ program for bloodstain pattern analysis is an excellent forensic tool that allows bloodstain pattern analysts to simply and quickly analyze patterns of projected bloodstains at bloodletting crime scenes. Although the program has been in use for a number of years, few validation studies have been carried out. In this work, 18 bloodstain targets were created, and then analyzed independently by a number of trained bloodstain pattern analysts (N = 8-11) using the BackTrack™ programs. The results indicate high precision, demonstrating that a number of investigators, analyzing the same scene, will arrive at approximately the same result with the program. The accuracy of the results is also very good, in keeping with previous validation studies.

Introduction

The BackTrack™ suite of computer programs uses Directional Analysis to provide bloodstain pattern analysts with a quick and accurate method of processing a bloodletting crime scene [1,2]. The stains left by blood droplets striking a wall are digitally photographed and then entered into the computer program along with data related to each droplet's Y- and Z-coordinates on the wall. Directional Analysis computes a virtual string for each stain that is a straight line attached to each stain extending outward in 3-D space with a direction that is equal to the direction of impact of the blood droplet. The top view of the virtual strings provides the analyst with a means of accurately determining the location of the blood source in two dimensions, in the plane of the floor. The side view of the strings then allows for an estimate of the upper limit of the third dimension, the height of the source. Only an upper limit is possible because the speed and size of the droplets are quantities unknown to the investigator. BackTrack™ offers the analyst the advantages of speed and ease of use.

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The top view of the virtual strings assumes that the flight paths of the blood droplets will be straight lines. Although gravity and air resistance will affect a droplet's flight, when viewed from above, these effects are not seen. The parabolic flight of a projectile remains in a plane perpendicular to the ground, and the BackTrack™ top view is looking down on the "edges" of these planes and seeing them as straight lines. The analogy would be to looking down on a ball being thrown between two children. Regardless of the height of the ball's flight, when observed from above, the ball simply travels in a straight line between the two children.

The side view, on the other hand, will be affected by the curvature of the flight paths. If a droplet has started to fall before it hits the wall, extending the path back as a straight line will take the path above the actual blood source location. Proper stain selection, choosing fast upwardly-moving droplets, will give the best estimate for the Z-coordinate, since the flight paths will most closely correspond to straight lines.

Despite the fact that BackTrack™ has been in use for a number of years, very few validation studies have been documented [3]. A previous publication took advantage of the fact that the software was being informally validated whenever the use of the computer program was taught [4]. In this case, over a hundred trials carried out over a number of years by students being taught how to use the program were collected and examined. The differences between the known values of the X-, Y-, and Z-coordinates of the blood source positions and those calculated by the students using BackTrack™ varied by up to 30 cm. However, the overall average difference (N = 122) in the worst dimension was less than 7 cm.

In the previous study, each target was analyzed only once by a single group of students [4]. When the computed values differed markedly from the known values, it was unclear if the discrepancy was due to the inexperience of the students, a poor choice of stains, a problem with the program, or if it was simply a difficult target to analyze. In the current study, a number of analysts were asked to process the same targets. In this way both precision and accuracy could be addressed. By calculating average values and standard deviations, it will be possible to comment on the repeatability of the process. A small standard deviation would indicate that different analysts examining the same pattern would come to the same conclusion with respect to the position of the blood source. A large standard deviation would require further explanation. The differences between the average values from a number of analyses will speak to the accuracy of the BackTrack™ programs. As in the previous study [4], the differences are expected to be small. A similar test is being carried out by members of SWGSTAIN [5].

Method

Six different laboratories were asked to create single-blow bloodstain pattern targets. A small pool of blood, approximately 10 mL, was placed on a flat surface at a known X-, Y-, and Z-position, and struck with a hammer. In each location, one individual created the pattern, and a second chose the stains for analysis. In this way, the choice of stains would not be influenced by prior knowledge of the location of the blood source. The chosen stains were measured in the Y- and Z-direction, a scale was affixed close to the stain, a plumb line was drawn, and the stain was digitally photographed. The images, measurement data, and the known source location data were sent to a central site from which the images and measurement data were sent to various locations for BackTrack™ analysis. In each location, BackTrack™/Images (Forensic Computing of Ottawa) and BackTrack™/Win (Forensic Computing of Ottawa) were used to analyze the images that were submitted. In laboratories where patterns were previously created, the analysts were requested not to process their own patterns. A typical top view and side view used in the analysis of one of the targets is shown in Figures 1a and 1b. The top view can be used to determine the X- and Y-values corresponding to the location of the blood source. The side view is then used to determine the approximate height of the blood source. The values for X, Y, and Z were collected from the various laboratories, and averaged. The standard deviation was calculated using the conventional equation [6]:

$$\text{S.D.} \;=\; \sqrt{\left[\, \sum (X_i - X_{av})^2 / (N - 1) \,\right]} \qquad \text{(I)}$$

where N is the number of values being considered, X_i refers to the individual X-values from i = 1 to i = N, and X_{av} is the average value.

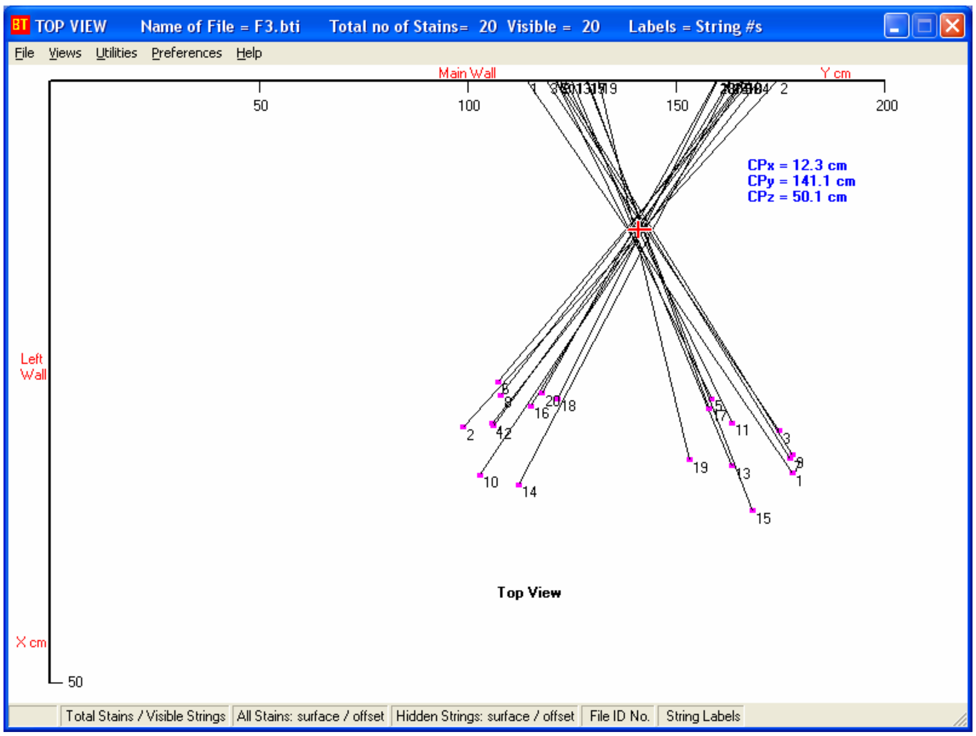

Figure 1a. Top view of Pattern #18. The average position for the line-crossings corresponds to the X- and Y-coordinates of the blood source location, in the plane of the floor.

Results

Table 1 lists the average X-, Y-, and Z-values for the blood source locations, along with the standard deviations. In all cases, the standard deviations were quite small, with the greatest values being 6.44 cm for the X-value in Target # 11, 3.38 cm for the Y-value in Target #13, and 7.02 cm for the Z-value in Target #2. Only four standard deviations were greater than 4 cm. Table 2 lists the known locations of the blood source for each of the targets, as well as the difference between the average calculated value and the known value. Although the difference was as great as 23.1 cm for the Z-value in Target # 16, the average differences between the known values and the average BackTrack™ values were only 2.5 cm in the X-direction, 2.3 cm in the Y-direction, and 8.1 cm in the Z-direction.

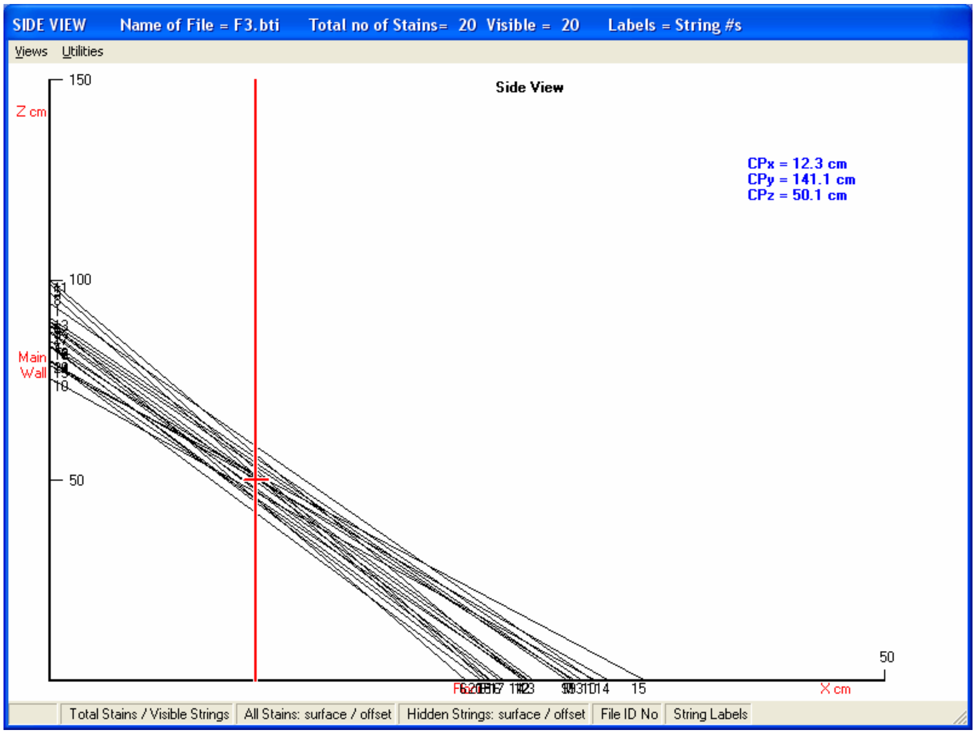

Figure 1b. Side view of Pattern #18. The vertical line corresponds to the X-coordinate calculated from the top view. The Z-values corresponding to where the strings cross the vertical line are averaged to determine Z, the height of the blood source.

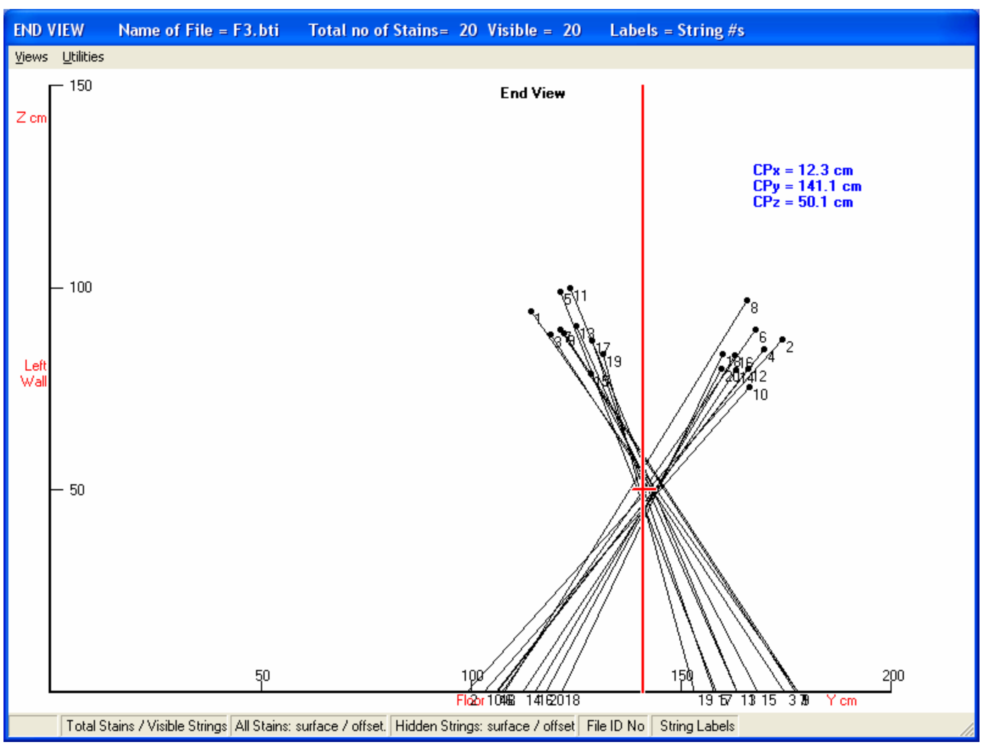

Figure 1c. End view of Pattern #18, facing the front wall on which the stains are located.

Target #	X/cm	S.D. (N =)	Y/cm	S.D. (N =)	Z/cm	S.D. (N =)
1	41.7	3.83 (10)	114.4	1.24 (10)	25.7	2.09 (10)
2	26.6	2.22 (11)	176.5	0.78 (11)	18.2	7.02 (11)
3	36.5	3.12 (11)	49.4	0.74 (11)	91.8	4.01 (11)
4	20.9	1.89 (10)	78.3	0.86 (10)	31.5	0.90 (10)
5	46.8	3.41 (10)	81.1	0.88 (10)	49.7	2.31 (10)
6	34.5	2.66 (10)	85.5	0.66 (10)	59.4	1.72 (10)
7	20.2	1.43 (11)	54.5	1.64 (11)	115.1	3.31 (11)
8	24.9	1.56 (9)	80.9	1.06 (9)	115.6	2.10 (9)
9	27.7	1.38 (9)	79.1	1.76 (9)	123.6	1.49 (9)
10	23.6	2.31 (10)	431.8	1.76 (10)	82.5	2.97 (10)
11	40.3	6.44 (10)	540.7	2.21 (10)	118.2	5.42 (10)
12	16.1	0.96 (11)	26.6	0.46 (11)	121.1	2.54 (11)
13	29.6	1.37 (9)	271.9	3.38 (9)	114.6	0.88 (9)
14	30.0	0.97 (8)	138.0	1.88 (8)	93.5	0.95 (8)
15	25.7	1.65 (11)	244.6	1.33 (11)	100.0	1.76 (11)
16	57.1	3.53 (10)	126.5	2.32 (10)	127.4	2.71 (10)
17	33.4	2.09 (11)	102.9	2.25 (11)	107.3	1.47 (11)
18	13.2	1.26 (11)	141.3	1.58 (11)	49.6	1.71 (11)

Table 1. Average X-, Y-, and Z-values calculated using BackTrack™ for the blood source locations, along with standard deviations (N = 8-11) calculated using equation I.

X/cm	X_{av}/cm	ΔX/cm	Y/cm	Y_{av}/cm	ΔY/cm	Z/cm	Z_{av}/cm	ΔZ/cm
46.0	41.7	4.3	115.0	114.4	0.6	12.0	25.7	13.7
30.0	26.6	3.4	176.0	176.5	0.5	2.5	18.2	15.7
38.0	36.5	1.5	50.0	49.4	0.6	81.3	91.8	10.5
21.0	20.9	0.1	80.0	78.3	1.7	32.0	31.5	0.5
48.0	46.8	1.2	83.0	81.1	1.9	41.0	49.7	8.7
36.0	34.5	1.5	89.0	85.5	3.5	52.0	59.4	7.4
24.0	20.2	3.8	52.5	54.5	2.0	114.0	115.1	1.1
28.0	24.9	3.1	82.5	80.9	1.6	114.0	115.6	1.6
31.0	27.7	3.3	80.0	79.1	0.9	121.0	123.6	2.6
27.0	23.6	3.4	439.0	431.8	7.2	75.0	82.5	7.5
40.0	40.3	0.3	543.0	540.7	2.3	105.0	118.2	13.2
20.0	16.1	3.9	23.0	26.6	3.6	105.0	121.1	16.1
26.0	29.6	3.6	275.0	271.9	3.1	116.0	114.6	1.4
25.0	30.0	5.0	145.0	138.0	7.0	93.0	93.5	0.5
25.0	25.7	0.7	245.0	244.6	0.4	95.0	100.0	5.0
61.1	57.1	4.0	129.5	126.5	3.0	104.5	127.4	22.9
34.4	33.4	1.0	102.0	102.9	0.9	90.7	107.3	16.6
13.5	13.2	0.3	142.0	141.3	0.7	48.8	49.6	0.8

Table 2. Known values compared to the average calculated X-, Y-, and Z-values for the blood source locations. The average differences in each direction (N=18) are: ΔX = 2.5 cm ; ΔY = 2.3 cm ; ΔZ = 8.1 cm.

Discussion

The standard deviations for the X-, Y-, and Z-values for all 18 patterns were very small, ranging from 0.46 to 7.02 cm, with the majority (44/54) being less than 3 cm. These small values indicate that a number of experienced analysts examining the same crime scene would come up with approximately the same BackTrack™ results. A small standard deviation could be interpreted as illustrating that the precision of the method is quite good.

The accuracy of the results can be addressed by examining the values in Table 2. For the most part, in agreement with previous studies [3,4], the accuracy of the BackTrack™ programs is very good. As might be expected, for each target the largest discrepancy between the average value calculated and the known location was usually in the Z-direction. According to Directional Analysis, the X- and Y-values for the blood source location will be estimated very well. Any curvature of the flight paths of the blood droplets will not affect the analysis. Indeed, even blood droplets travelling in a downward motion can still be used in BackTrack™ calculations for the X- and Y-coordinates [7]. The Z-value, however, is estimated from the side view of the virtual flight paths. If a droplet is slow-moving, it will be starting to fall before it hits the wall. Tracing the flight path back as a straight line will show the droplet originating from a point directly above the actual blood source location. As a result, the Z-coordinate is often overestimated. The precision of the results, as shown in Table 1, implies that the cohort of analysts collaborating here would all calculate a similar overestimation of the Z-value as seen, for example, in Targets #2 and #3.

Targets #2 and #3 come in for special consideration due to the fact that the known value of Z is quite small. As a result, some of the strings seen in the side view may hit the floor before reaching the appropriate X-value away from the wall, and will, thus, not contribute to the calculation of Z. If these strings could be drawn through the floor and added to the average as negative values, they might have pulled the value of Z down closer to the true value. On the other hand, a clever modification of the data, though not used here, would have been to add a constant correction factor to every Z-value to raise the entire pattern up from the floor. This would not have affected the calculation of the X and Y positions, but would have ensured that all strings were considered in the Z calculation. Once Z had been determined, the correction factor would have been subtracted from the result to get a true Z-value. This type of manipulation, which could be brought into play whenever the blood source seems to be close to the ground, would not be possible with other analysis techniques. Similarly, for Patterns #10 and #11, a correction factor could be subtracted from the Y-values in order to bring the pattern closer to the origin for easier analysis. Once a Y-value was calculated, the correction factor would be added to get the true value.

In order to expedite the analyses, stains from each target were chosen and photographed in the laboratory in which the targets were created, rather than having each analyst choose and photograph his or her own stains. If each analyst had been given the entire pattern to examine, the stains chosen might have been different, and might have resulted in different final values. The SWGSTAIN experiments involve sending the entire pattern to each participant, so that the entire process, from stain selection to final calculation, will be done by one person [5]. However, having every analyst use the same stains produces standard deviations that relate to only the software itself, without the added variable of varying stain selection.

Conclusion

This validation study shows that a number of analysts examining the same bloodstain pattern with the BackTrack™ suite of programs will generally come up with very similar results. As well, the results generated will be quite accurate, in agreement with previous studies.

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