Mini Review

The Study of Bloodstain Patterns Release from Blood Drops in a Crime Scene

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Abstract

A supervised learning model has been developed to predict the source of a passive blood drop from the characteristics of the drop (such as length, breadth, angle of impact, fall height, interaction features). Again, these characteristics are only available for a plain/smooth, non-absorbent target surface.

Introduction

Locard's exchange principle states that "every time an individual makes contact with another person, place or thing, it results in an exchange of physical materials" Welding [1]. The study of evidence at a crime scene is particularly based on this principle. Bloodstain pattern analysis is defined as 'the scientific study of the static consequences resulting from dynamic blood shedding events '[2]. The detailed study of bloodstain patterns obtained from a crime scene could prove to be invaluable evidence for part/full crime scene reconstruction, in testing the credibility of the statements of the victim, suspect, bystander/eyewitness (if any). As per the International Association of Bloodstain Pattern Analysts (IABPA), a bloodstain pattern is defined as 'a grouping or distribution of bloodstains that indicate through regular or repetitive form, order, or arrangement the manner in which the pattern was deposited' [3]. Based on the different case studies presented at the IABPA conference [4] the authors are of the view that of the different types of bloodstain patterns, the most common stain patterns visible at the crime scene, particularly in the case where the victim was found to suffer blunt force injuries, are saturation, impact, cast off and transfer stain patterns. Violent criminal activities under most circumstances are accompanied by large spillage of blood. A bloodstain formed due to accumulation of liquid blood on an absorbent surface such as carpet, fabric, clothing, bed sheet, curtains etc. is commonly referred to as 'Saturation Stain' [3]. Large amount of blood outflow occurs when a person suffers serious head injuries owing to hammer strike or when struck on the head with a blunt ended object, such as a golf stick, candle stand, sticks etc. Under such circumstance one could evidently expect to see stained carpets, clothes etc. depending on the position of the victim, perpetrator and bystander (if any). Again, as a result of the impact mechanism or rather the impact force of hit, certain stain patterns

are developed. Because these stain patterns are developed as a result of an object striking liquid blood, these are commonly known as 'Impact Pattern' [3]. Bloodstain patterns formed as a result of contact between a blood-bearing surface and another surface is commonly referred to as Transfer Stains by the IABPA [3]. Blood bearing fingers, bloody weapons, half bloody or bloody shoes etc. leave transfer stains in a crime scene as a result of the sequence of events that had occurred at the crime scene. Thus Transfer stains in coherence with other bloodstain patterns such as Voids, Saturation Stain, Cast-off patterns etc. can be effectively used for part/full reconstruction of crime scene.

The proposed article is a brief record of the various interdisciplinary, significant contributions that have been made towards part/full crime scene reconstruction from bloodstain patterns along with a precise documentation of the experiments, analysis conducted /conceptualized by the authors to mend identified gaps within the knowledge domain.

Literature Review

Research pertaining to any sub-domain of Forensic Science (Bloodstain Pattern Analysis, in the given context) is particularly inter/multidisciplinary. Laber [4] experimentally elucidated that blood drops falling freely under the action of gravity cannot be assigned a constant volume. By way of experiments undertaken he inferred that the drop volume is a function of its source of origin and vary from less than 0.01ml/drop to greater than 0.1ml/drop [4]. The work also outlined that with the increase in drop volume was directly proportional to the increase in the diameter of a regular stain formed on a non-porous/non-absorbant, visually plain surface('defined' surface) [4]. Extending the work of Laber [4], Smith et al. [5] confirmed that the diameter and spines of a regular

bloodstain was positively correlated to the blood drop diameter and impact velocity. Additionally, increase in surface roughness resulted in reduced stain diameter and merging of spines [5]. With crime scene as the context, Ross [6] showed how the volume of blood drop from a range of objects that could be used as weapons varied. Knock et al. [7] proposed a mathematical model to predict the impact velocity and position of the source of a bloodstain. In coherence with the perspective of Ross [6], Kabaliuk et al. [8] studied the size of droplets free falling from objects that were representative of hand held objects. Kabaliuk et al. [8] reported that the number of accompanying droplets increased linearly in accordance with the increase in the object size.

Proposed Method

The size of the primary drop was reported to decrease from a blunt to a sharp object [8]. On similar lines, if the possible sources of a blood drop stain or trail could be identified then that would contribute to the reconstruction process.
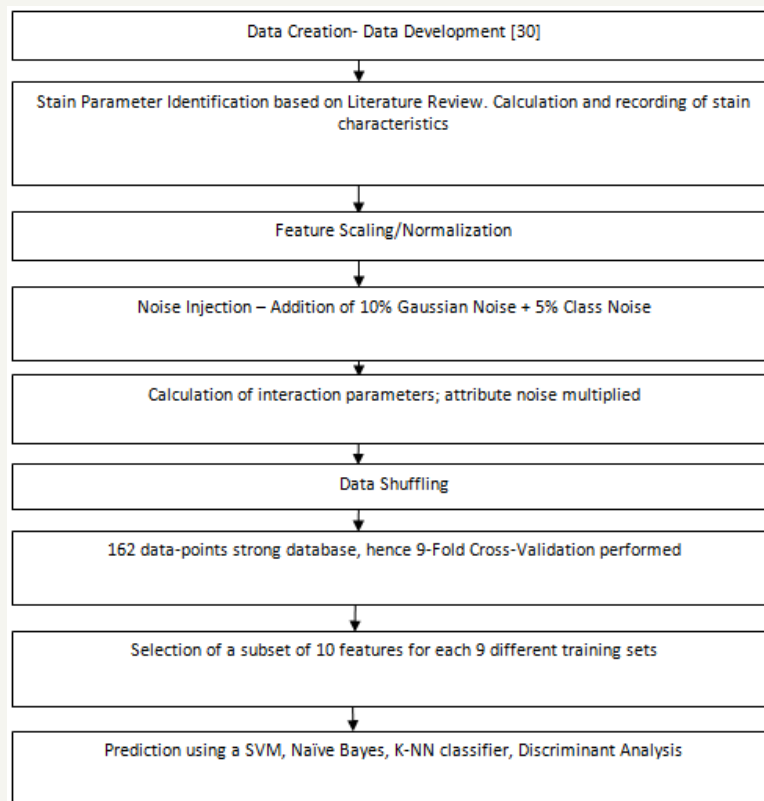

Figure 1: The basic steps to predict the source of a blood drop.

In order to mend this loophole within the domain, a supervised learning model has been developed to predict the source of a passive blood drop from the characteristics of the drop (such as length, breadth, angle of impact, fall height, interaction features). Again, these characteristics are only available for a plain/smooth, non-absorbent target surface [9]. The model developed can distinguish between blood drops from target surfaces whose radiuses vary, thereby making it possible to predict the possible source of a drip stain from other circumstantial evidence present at a crime scene. A Kruskal Wallis test revealed that when similar physical mechanisms and a constant target surface were employed there was significant difference in the bloodstain length ($\chi2=10.752$, df=1, p=0.001<0.01) and breadth ($\chi2=12.622$, df=1, p=0.001<0.01) for the blood drops emanated from a subcutaneous syringe of capacity 2.5cc provided with a needle 0.55x25mm/24x1 against blood drops emanated from the same syringe without needle. The test also revealed that no significant difference was recorded for the total number of satellites ($\chi2=1.776$, df=1, p=0.183>0.01) formed for blood drops emanated from a syringe with and without needle. In drawing up a logistic regression for prediction the Wald criterion revealed that only 'Breadth' of the stain was significant (p=0.002<0.01) towards prediction of source radii from which the blood drop had passively dripped. Provides a brief summary of the Accuracy, Sensitivity and Specificity values obtained for source radii prediction for the different classifiers, namely, KNN, SVM, Discriminant Analysis and Naïve Bayes. The Figure 1 describes the basic steps to predict the source of a blood drop from the features of drop. It describes data model developed to predict the source of single passive drip stains on a plain, smooth, non-absorbent target surface. Nutt [9], Clements [10] and Lee [11] can particularly be credited with the detection of blood and enhancement of blood prints in the early 80's. Cresap by way of experimentation highlighted that the size of the bloody bare footprint can be small, large or equal to the actual foot size of an individual depending on the ability of the target surface to record the said print [12]. Cheeseman et al. [13] performed an evaluation of the refined fluorescein technique by comparing the same bloody

foot trails recorded on two different surface substrates [13]. Work by Atamturk [14] deals with sex estimation using features of footprint, foot and shoe size for an individual. The accuracy rate (84.6%) of sex determination by Atamurk's model [14] closely resembles the sex determination accuracy rate (85%) achieved by Wunderlich & Cavanagh [15]. Wunderlich and Cavanagh identified foot length as a prime determinant for sex determination [15]. The book by DiMaggio et al. [16] links the findings in the field of podiatry to real world crime scene scenario.

Conclusion

Research work on BPA in its very core is based on the age old Biblical dictum "Blood never lies". The fact that blood follows the laws of fluid mechanics and reacts similarly under similar physical conditions forms the basis of bloodstain pattern analysis. From the literature and from case study experience the authors conclude that the basic most common bloodstain patterns that an individual can expect to see when an individual is hit by a blunt ended object are–transfer stain patterns from fingers, weapon, saturation stain patterns, impact spatter, cast off pattern and even expired stain patterns on certain occasions.

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