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An Introduction to Bloodstain Pattern Analysis

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***Abstract*---The study of bloodstain patterns obtained from a crime scene could prove to be invaluable evidence for crime scene reconstruction, in testing the credibility of the statements of the victim, suspect, bystander/eyewitness (if any). This paper gives an introduction to the bloodstain pattern analysis with case studies.**

Index terms - Bloodstain Pattern Analysis (BPA), Crime Scene Reconstruction, Transfer Patterns, Knife Impressions, and hammer imprint

I. INTRODUCTION

The relevance of the article lies in the fact that analysts having clear idea of how these different factors could affect the formation of different weapon transfer stain patterns, shall be in a better position at understanding the probable mechanism that might have led to the formation of the stain. This knowledge is transferable to the study of other murder weapon transfer stain interpretation and shall aid proper sequencing of segments in a criminal event. The significance of the height of fall and the edge that touches the target surface first, cannot be particularly ruled out in analyzing hammer transfer stain patterns. Forensic Science particularly deals with presentation of evidence within a juridical setting. On similar lines, Stuart H. James's book on 'Scientific and Legal Applications of Bloodstain Pattern Interpretation' puts down rules for presentation of uncontaminated, relevant bloodstain pattern evidence within a juridical setting

It is possible to develop a tool that is efficient at analyzing and probabilistically predicting a particular sort of transfer stain. However, development of a dataset consisting of a large variety of weapon transfer stains formed by different angle of inclination of tool drop, dimension of tool edge, fall height, velocity of hit etc. stands integral.

Development of a tool, development of a database that has sufficient variation and comparable representation of each possible class type stands out to be the biggest challenge. Once a dataset has been prepared, semi-supervised learning techniques could be used to develop an appropriate tool.

From practical experience, the authors are of the opinion that in the absence of a murder weapon from the crime scene, other circumstantial evidence such as wound analysis, absence/presence of objects at a crime scene stand integral in weapon transfer stain analysis and hence identification of the murder weapon used. The factors highlighted in this study shall help pattern analysts at better understanding and analysis of transfer stain patterns at a crime scene. Hence, this study shall also aid effective part reconstruction of the criminal event.

Knife impressions are often quite pronounced for an analyst to match them up with a suspected knife .The weight of a knife is highly unlikely to produce a void pattern in a blood soaked surface by reverse capillary action

The paper aims at studying cases round the world. This very reason probably makes hammer a murder tool of choice among criminals over the world like Adam Moss(Sioux City, Iowa, USA)[1], Alexander Yuryevich Pichushkin (Moscow, Russia)[2], Brian Blackwell (Merseyside, England, UK)[3], Christine Schürrer(Arboga, Västmanland County, Sweden)[4], KampatimarShankariya(Jaipur, India)[5], Ma Jiajue(China)[6], Maoupa Cedric Maake(Johannesburgo area, South Africa)[7].

In 2011, The Federal Bureau of Investigation (FBI) chart reported that the number of individuals killed (496) by blunt objects (such as club, hammer, golf stick, candle-stand etc.) by far

superseded the number of individuals killed by rifle or shot gun [8]. With regard to the study of hammer transfer stains, it might be interesting for the reader to know that as per the FBI chart figures the number of individuals killed by hammer or club hit by far outnumbered the number of individuals killed by rifle or shot gun [8].

II. CASE STUDIES

When it comes to documenting Bloodstain Patterns based on visibility of patterns to the naked eye there are in particular 2 types of bloodstain patterns/prints one could come across in real life – latent bloodstain patterns and visible Bloodstain Patterns. Given the fragile nature of bloodstain patterns at a crime scene, stains are often accompanied by noise or are superimposed by other stains in course of subsequent events at the crime scene.

A male victim was discovered with multiple sharp force injuries. The injuries consisted of penetrating wounds on back, and neck, and cutting wounds to the hand. On white bedsheets next to the victim were stain patterns that were consistent with bloodstain patterns. The bedsheets appeared to have been crumpled as if suspect to wipe blood from a knife. Two kitchen knives were located at the scene. The knives were also found with a telephone and other bloody cloths.

The BPA analyst can simulate the crime scene based on statics and extrapolate theory from the numerical methods. By way of experience, an individual can clearly understand the difficulty of visualizing bloodstain patterns on dark coloured fabric. The study undertaken by Ted Silenieks, Russell Cook and Kareana Turner used hyper-spectral imaging to assess the contrast between bloodstains and different dark coloured fabrics at defined wavelengths over the visible and near infrared range.

An elderly female was found deceased on the floor of the kitchen of her house. Shewas found to have multiple sharp force injuries to herright arm, torso, left hand, andneck. Injuries to the arm and neck were consistent with penetrating puncture wounds. The wound to the hand and neck was consistent with cutting wounds. A kitchen knife and a kitchen towel were found near the head of the victim. When crime sceneinvestigators rolled the victim's body to the left the victim's right hand positioned over the knife on the towel. Her sari had numerous stains consistent with bloodstains.

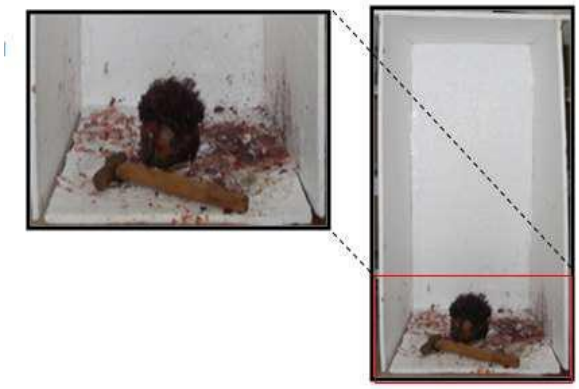
III. EXPERIMENTAL SETUP

The authors used porcine blood to recreate transfer stain patterns that one can expect to see in a crime scene. Porcine blood was used for experimentation because it is quite similar to human blood[9][10]. Blood was legally procured from Kolkata Municipal Pig Slaughter House, Tangra Kolkata, India. Given that fresh blood coagulates over time, 1100 IU of Heparin Injection was added to fresh pig blood to preserve the colloidal consistency of blood. It might be interesting to mention that adding anticoagulant does not alter the viscosity and specificity of blood.

The authors simulated the event of a hammer head hit within the laboratory setting using a hollow coconut shell and blood soaked wig. Figure1 illustrates the experimental setup developed by the authors.

Six hammers were selected based on case study and availability at the local marketplace. The 6 different types of hammers that were used for the study are – a ball-peen hammer, a sledge hammer, a claw hammer, a cross and straight peen hammer, a brick hammer and a special hammer.

The simulated head was hit with the edge of each hammer for 10 consecutive times, then dropped into a 30 cc. blood pool and then picked up and again dropped from a height of 40, 60 and 80 cms respectively.



In line with the experiments conducted by Pitrowski[11], the authors did take into account the head movements that could occur after a couple of head hits.

IV. RESULTS

As suggested by many forensic analysts, bloodstain pattern analysis is not particularly a new discipline in itself. The roots of bloodstain pattern analysis as forensics know it in the modern day world dates back to the 1800s.To understand the different stain patterns it is indeed important to have a clear understanding of the physical mechanism and scientific principles that control the fall, spattering of blood at the crime scene.

The atmospheric conditions on the day the experiment was performed have been summarised in Table 1.

Forces of cohesion, adhesion, gravitation, surface tension primarily control the formation of bloodstain patterns at a crime scene of the Non-Newtonian fluid, blood. Blood spatters only when other forces exceed the surface tension that holds the blood molecules together[12].

The atmospheric conditions on the day the experiment was performed have been summarised in Table 1.

Atmospheric Parameters	Values
Dry Temperature	23°C (approx.)
Wet Temperature	26°C (approx.)
Relative Humidity	77-78%
Wind Conditions	Not Windy

Table 2: Atmospheric conditions of the area where the experiments were performed

As per the laws of physics, the fall height of the hammer significantly affects the velocity with which the hammer touches the surface[12].The gravitational force with which the bloody hammer hits the surface exceeds the surface tension. Given the comparatively larger quantity of blood attached to the bloody face of the blood pool soaked hammer, blood was found to spatter more in its case. Thereby it can be concluded that the quantity of blood or blood molecules attached to the hammer , the surface area of hammer exposed to blood, the angle of inclination at which the hammer falls as also the edge , face or other part of the hammer that first strikes the surface influence the formation of the transfer stain.

The Transfer Stain images obtained from a sledge hammer have been duly represented in Figure 2.

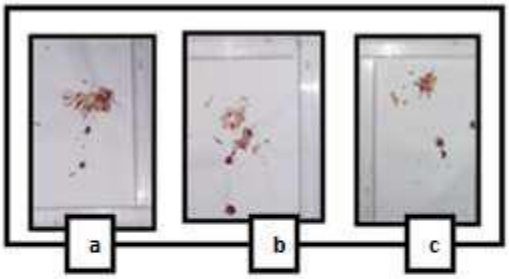


Figure 2: After 10 consecutive head hits, sledge hammer was dropped into a 30 cc. Blood pool, picked up and then dropped on non-absorbent paper from a height of (a) 40 cms, (b) 60 cms and (c) 80 cms respectively

The formation of the Transfer Stain patterns can partly be explained by using the concepts of physics introduced by Rod Cross with respect to the free fall of top heavy elongated objects. As per the findings of Rod Cross, an elongated object or a top heavy elongated object (like a hammer) when dropped to the ground will have a falling or rotating phase while it remains in contact with the ground or target surface [13]. This centripetal force on the object acts towards reducing the normal reaction force exerted by the ground or target surface on the object (in this case hammer). However, the hammer dimension, mass distribution do significantly influence the transfer stain formed by the hammer.

Again in this respect, it would not be out of place to mention that even if a hammer is dropped face down in a 30 cc. blood pool, it is not necessary that the entire front face of the hammer will get soaked in blood.

Figure 3: The side view of a sledge hammer. The red coloured triangle represents the area of the hammer that doesn't come into direct contact with the ground when the hammer is placed on the ground.

The flow of blood pool is often majorly restricted due to viscosity and other external obstructions that resist blood flow. Hence when a hammer falls in a blood pool under gravity, the portion of the hammer in blood pool displaces volume of blood that is equal to the volume of the portion of hammer that is fully or partly immersed in blood. Given the hammer dimensions, the volume of blood in the pool determines to what extent the hammer will be soaked/immersed in the pool. The above figure illustrates this phenomena (refer Figure 3). Thus, the initial angle of inclination at which the hammer is dropped, the coefficient of friction, the length and mass distribution of a hammer influence the magnitude and direction of displacement of the hammer as also the stain pattern one could expect to see in case of a blood bearing hammer[13].

V. CONCLUSION

The height of fall, the quantity of blood attached to the surface of hammer, the inclination at which the hammer is dropped, friction coefficient of the material of hammer, length and mass distribution of the hammer and the edge at which the hammer strikes the target surface influence the transfer stain pattern formed. However, tracing back the actual parameters that have led to the formation of a particular hammer transfer stain image is often difficult due to large variability in the hardness of the target surface, blood molecules attached to the surface of the hammer, atmospheric conditions and angle of inclination of hammer at the time of fall.

Given that other blunt ended objects could also produce similar stains, therefore, it is not easy to say that the test images are sufficient for making an absolute identity or an association between a scene bloodstain image and suspect object/s. Furthermore, one can only probabilistically predict that a certain bloodstain pattern was formed as a result of an action by an object. Thus, weapon transfer stains should only be studied in coherence with other relevant circumstantial evidence, to put together the missing blocks when reconstruction a particular crime scene.

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Authors Profile

Prof.(Dr.) Samir Kumar Bandyopadhyay has been conducting research for the last 22 years in Image processing, particularly in the field of Biomedical Engineering, Biomedical Imaging and Forensic Science. He has worked on a wide array of projects such as Pattern recognition/identification in Disease Diagnosis, Graph Algorithms, Application of Neural Networks in Graph Algorithms, Mobile Computing, Hand-written signature verification, Graphical Password Verification, Steganography and Water-marking. He has published over a hundred and three(103) Research papers in reputed International Journals including IEEE Transactions, Springer, Elsevier, ACM etc. in Computer Science and Engineering.He also has fourty four(44) and ten(10) Research papers papers published in International and National conferences respectively, organized by IEEE Society, Springer and other reputed Universities and Institutes etc., to his credit. Till date sixteen scholars(16) who have worked with him have received PhD degrees. At present , twelve scholars(12) are completing their PhD dissertation under his able guidance. He has examined several PhD theses in India and abroad. He holds 25 years of teaching experience at both the Undergraduate and Post-Graduate level at the University of Calcutta. At present he teaches, (a) Software Engineering,(b) Object Oriented System, (c) Research Methodology etc.

Nabanita Basu completed her B-Tech in Computer Science and Engineering from West Bengal University of Technology in 2010. She also completed her Bachelor of Arts in Journalism and Mass Communication in the same year itself. During her short work tenure of 6 months at Capgemini India Private Limited, she got herself certified as a Java Developer (Sun Certified Java Programmer). It was during this period that she also completed certification in Pegasystems(Certified System Architect Pega PRPC v6.1). In October, 2012, she completed Master of Advanced Computer Science program at the University of Manchester, UK. Thereafter she completed her Master of Research in Security and Crime Science from University College London, UK. In the course of the program she also got herself certified as a Bloodstain Pattern Analyst(Basic Course) by the International Association of Bloodstain Pattern Analysts, USA(IABPA).