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An Improved Blood Splatters Analysis Technique

Utkarsha Chirmade[1], Namrata Sharma[2], B.S Patil[3]

[1]Sushila Devi Bansal College of Engineering, Indore

[2]Sushila Devi Bansal College of Engineering, Indore

[3]Professor, Govt .College of Engineering, Karad

Abstract: ***In different complicated crime investigation and solving the cases the forensic science is a key contributor. That involves the biology, chemistry, mathematics and physics for investigating the facts about the crime. Forensic science includes on more technique for crime scene analysis is known as bloodstain analysis. The bloodstain analysis enable the investigators to understand the crime scene, discover the kind of weapon used, speed of weapon, flight time of blood drops and the angle of weapon or impact. In this work the aim is to investigate about the blood strain analysis technique and to design a new technique for recovering the flight time, angle of impact and velocity of weapon. In this context first the crime scene image data is accepted as initial input. Additionally for finding the accurate analysis some additional inputs are also included such as high of impact, distance of blood drops and the line passing through the ellipse formed in the input image. Finally the velocity and flight time of blood drops are calculated using the law of motion and the trajectory analysis. The implementation of the proposed technique is provided using JAVA technology. Additionally the performance is computed in terms of time and space complexity of the implemented system. The performance of the proposed system demonstrates the proposed technique is effective and low resource consuming technique.***

Keywords: Forensic, bloodstain analysis, trajectory analysis, flight time, velocity and angle

1. Introduction

The domain of computation and their applications are expanding day by day. Among various application domains of computations now in these days in forensic science it also becomes popular. Basically the forensic science is a domain or subject of investigation of criminal activities. That is responsible for preservation, investigation and collection of criminal facts that helps to explore the crime. In this proposed work the domain of forensic science is key area of study and fact collection. In addition of that the effort is made in order to provide enhance and efficient approach for finding the blood splatter trajectory.

The analysis of blood splatter trajectory is also termed as Bloodstain pattern analysis. That is aimed to helping investigators draw conclusions about the nature, timing and other details of the crime. Bloodstain pattern analysis draws on the scientific disciplines of biology, chemistry, mathematics and physics. In this presented work the investigation is limited on the physical characteristics of crime scene analysis. A single spatter of blood is not enough to determine the Area of Origin at a crime scene. But in this presented work for demonstrating the proposed working model the work is focused on the single drop based technique. Therefore the image processing technique (i.e. edge detection) is included initially for finding the curve and the angle of impact. Additionally for analyzing the velocity and the flight time estimation the low of motion and trajectory is analyzed.

2. Proposed Work

This chapter demonstrates the proposed methodology of blood splatter analysis. In this context the method formulation for analyzing the blood spot in order to recovering the speed and angle of weapon operation is investigated. This chapter includes the basic theory and the detailed methodology description for accomplishing the required goal.

A. System Overview

Forensics is a domain of engineering and science which is used for analysis of any crime scene. Here the different concept of engineering, chemistry, physics and others are included for finding the different facts that can help for discovering the actions and reason of crime. Now in these days the forensics is also performed using the image processing concepts. By using the image processing concepts the crime scene is investigated and different facts about the particular crime is investigated. In this presented work the main aim is to use the image processing concepts for analyzing the blood splatter. The blood splatters of any crime scene used to find the type of weapon used, the angle on which the weapon is operated and the speed of weapon. Among these facts the angle and the speed of weapon is calculated in this work. Thus a new method for computing these facts is introduced in this work.

The proposed technique is based on the blood trajectory analysis. Thus the low of motion and the concept of projectile are used for formulation and analysis of blood splatters. Using both the techniques the main aim is to compute or recover the information about the velocity and angle of weapon operation. Therefore the three basic equations of law of motion and the concept of trajectory analysis are used for finding the required goal. The proposed technique requires some additional input for finding accurate information i.e. initial position of body and the height of weapon operation. Using these initial inputs the proposed mathematical model is formulated. In addition of that some concepts of the image processing is also included for recovering the blood spots and the edges of the blood splatter images. The next section provides the detailed understanding about the proposed concept and their outcomes.

B. Methodology

The proposed methodology for analyzing the speed and angle of weapon is computed in this section. The figure 1 shows the proposed model how the processes are taken place.

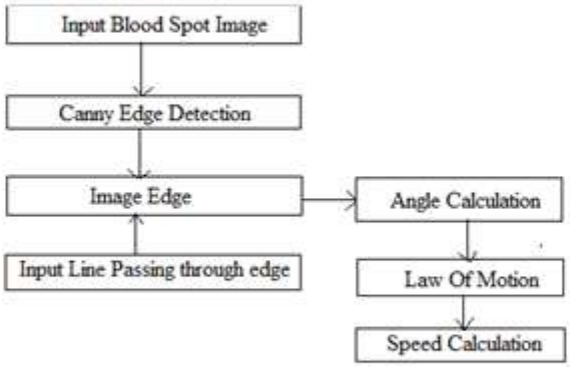

Figure 1: Proposed Model

Input blood spot image: that is the initial input of the system, user select a blood spot image from the local disk and input to the system. This file input contains the blood spots which is need to be analyzing by the proposed system.

Canny Edge Detection

The edge detection provides the approach to minimize the amount of data in image. This kind of image analysis leads to preserve the structural properties of image. In literature a number of methods available here the canny edge detection approach is used which is given by John F. Canny in 1986[13, 14]. The algorithm works in five different phases:

1) **SMOOTHING**: the aim of this phase is to remove noise from the input image.
2) **FINDING GRADIENTS**: in this phase edges are identified using the gradients of the image because the edges have big magnitudes.
3) **NON-MAXIMUM SUPPRESSION**: this phase is responsible to locate only local maxima as edges.
4) **DOUBLE THRESHOLDING**: possible edges are also identified by using thresholding.
5) **EDGE TRACKING BY HYSTERSIS**: Final edges are obtained by composing all edges that are not involved as strong edge.

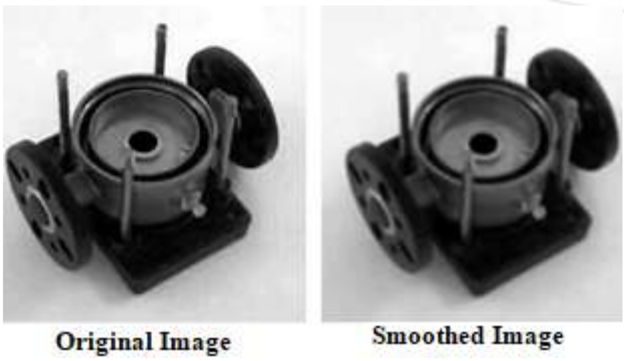

Figure 2: Smoothing Effect on Image

During the photography using any kind of camera it is expected that the images will contain some amount of noise. This noise can affect the accurate edge recovery therefore to prevent noise a filtering process is used here. This filtering technique for removal of noise from image is termed as smoothing. To make smooth image Gaussian filter is frequently used here.

3. Finding Gradients

The gradient magnitudes are also called as edge strengths. That can be computed using Euclidean distance by applying the Pythagoras law.

$$|Gr| = \sqrt{Gr_x^2 + Gr_y^2}$$

That can also be computed using Manhattan distance, which is less computationally complicated as compared to Euclidean distance.

$$|G| = |G_x| + |G_y|$$

Gr_x and Gr_y are the gradients in the x and y directions.

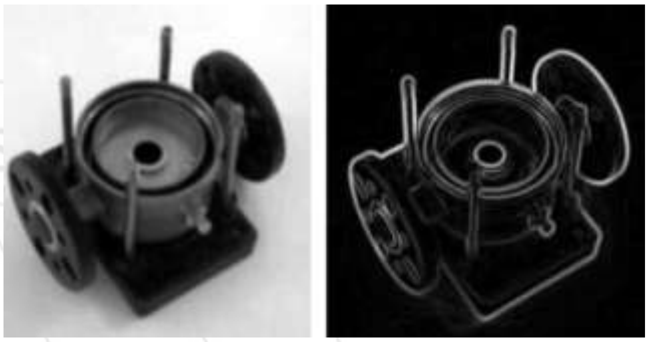

Figure 3: Gradient Magnitude of Image

The Euclidean distance evaluate has been applied to the test image. The computed edge strengths are evaluated to the smoothed image in figure 3. The figure 3 (b) is an image of the gradient magnitudes. That indicates the edges clearly. Here given edges are comprehensive and not indicating the edges precisely. Therefore need to make it clearer; the directions of the edges are needed to be compute.

$$\theta = arcTan\left(\frac{|Gr_y|}{|Gr_x|}\right)$$

Non-Maximum Suppression

The reason of this step is to renovate the "blurred" edges in the image of the incline magnitudes to "sharp" edges. Therefore it is performed by preserving the entire local maxima in given image. Additionally the removal of other image contents is performed. The every pixel in gradient image is treated using the following steps of process:

Rotate the gradient image direction given as θ about 45◦.That is performed by using the 8-connected neighborhood points to the image.

Validate the strength of the edges of the target pixel with the edge strength of the pixel in the positive and negative directions. Suppose that if gradient direction is north (theta = 90◦), evaluate with the pixels to the north and south directions.

In this conditions if edge magnitude of target pixel is higher than preserve the value of the edge else remove the computed value.

Double Thresholding

The edge-pixels remaining behind the non-maximum repression step are (still) marked with their strength pixel-by-pixel. Many of these will probably be true edges in the image, but different maybe caused by noise or color variations for instance owing to rough surfaces. The simplest way to discern between these would be to use a threshold, so that only edges stronger that a certain value would be conserved. The canny edge detection algorithm uses double thresholding. Edge pixels stronger than the high threshold are marked as strong; edge pixels weaker than the low threshold are covered and edge pixels among the two thresholds are marked as weak.

Edge Tracking By Hysteresis

Strong edges are interpreted as "certain edges", and can immediately be included in the final edge image. Weak edges are incorporated if and only if they are connected to strong edges. The logic is of course that noise and additional small difference are unlikely to result in a strong edge (with proper adaptation of the threshold levels). Thus strong edges will (regarding) only be owing to true edges in the original image. The weak edges can either be owing to true edges or noise/color variations. The latter type will probably be disseminated independently of edges on the entire image, and consequently only a small amount will be located adjacent to strong edges. Weak edges owing to true edges are much further likely to be connected directly to strong edges.

Edge tracking can be implemented by BLOB-analysis (Binary Large Object). The edge pixels are divided into connected BLOB's using 8-connected neighborhood. BLOB's containing at least one strong edge pixel is then preserved, though additional BLOB's are suppressed. The consequence of edge tracking on the test image is shown in Figure.

Figure 4: Blob Analysis

Image Edge: the canny edge detection approach provides the images with clearer edges of blood spots. In further these edges are used for detection of other factors.

Input Line: the slop is computed by producing the additional input to the system in the image dynamically.

Angle Calculation: in order to calculate the angle using the input dynamic line the following technique is used for computing angle.

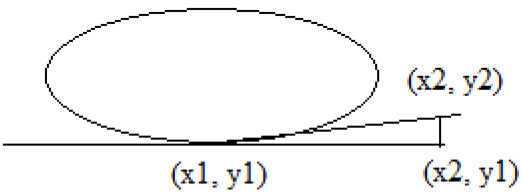

Figure 5: Computing angle

User first draws the line which is passing through the edge of the blood spot that is given using (x_1, y_1) and the last point where the line is end is denoted by (x_2, y_2). In order to evaluate the angle of the line a base line which is imaginary produced by the program accepts the initial co-ordinate (x_1, y_1) and second coordinate (x_2, y_1). Now using the formula of line we find the slop of both the lines as:

$$M_1 = \frac{y_2 - y_1}{x_2 - x_1}$$

And

$$M_2 = \frac{y_2 - y_1}{x_2 - x_1}$$

Thus the angle θ is computed using both the slops as:

$$\theta = tan^{-1}\left(\frac{M_1 - M_2}{1 - M_1 M_2}\right)$$

Law of Motion: after computing the θ now need to calculate the speed of the weapon. Thus for understanding the formulation consider the figure 2.6.

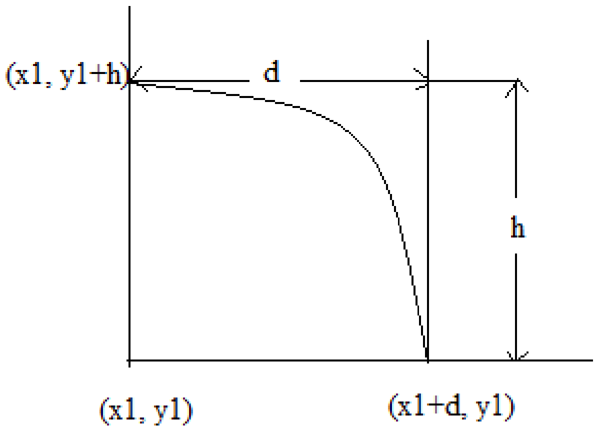

Figure 6: Location of person and blood spot distance

Form the above given figure we assumed that the person is standing on a position (x_1, y_1) and the weapon is stuck on the person at height of h thus the location new coordinates are $(x_1, y_1 + h)$ similarly the blood spots are observed on d distance thus the next coordinate is $(x_1 + d, y_1)$. Now need to assume some initial constrains for computing the speeds of weapon consider table 1 which contains the initial values of the above described technique.

Table 1: Initial Value

	Horizontal	Vertical
g	0	9.8
θ	cosθ	sinθ

Additionally we consider the three equations of the motion as:

$$v = u + gt \ldots\ldots\ldots\ldots (1)$$

$$s = ut + \frac{1}{2}gt^2 \ldots\ldots\ldots\ldots (2)$$

$$v^2 = u^2 + 2gs \ldots\ldots\ldots\ldots (3)$$

Speed calculation: in order to calculate the required speed we initially assumed that the initial speed of weapon is 0. By putting this value in equation (1) we get

$v = 0 + gt$

$$t = \frac{v}{g} \ldots\ldots\ldots\ldots (4)$$

Now by substituting the h value in equation (2) we get.

$$h = ut + \frac{1}{2}gt^2 \ldots\ldots\ldots\ldots (5)$$

Additionally by the equation (1) we get.

$$u = v - gt \ldots\ldots\ldots\ldots (6)$$

Putting the values of equation (6) into equation (5)

$h = (v - gt)t + \frac{1}{2}gt^2$

$h = vt - gt^2 + \frac{1}{2}gt^2$

$$h = vt - \frac{1}{2}gt^2 \ldots\ldots\ldots\ldots (7)$$

Now for vertical scenarios we put the value of g=-9.8 into the equation (7)

$h = vt + 4.9t^2$

using the equation (4)

$$h = \frac{v^2}{g} + 4.9t^2 \ldots\ldots\ldots\ldots (8)$$

on the other hand we utilize the equation (3) with the value u=0 for computing the value of v such that.

$v^2 = u^2 + 2gh$

$v^2 = 0 + 2gh$

$v^2 = 2gh$

$v = \sqrt{2gh}$

Now using the value of v the equation (8) can be written as:

$h = \frac{2gh}{g} sin\theta + 4.9t^2$

$-h\ sin\theta = 4.9t^2$

$\frac{-h\ sin\theta}{4.9} = t^2$

$$t = \sqrt{\frac{-h\ sin\theta}{4.9}} \ldots\ldots\ldots\ldots (9)$$

Now for horizontal computation is performed for computing the velocity, thus by equation (2)

$$d = ut + \frac{1}{2}gt^2 \ldots\ldots\ldots\ldots (2)$$

By using the table 2.1 the value can be written as:

$d = vcos\theta * t$

$d = vcos\theta * \sqrt{\frac{-h\ sin\theta}{4.9}}$

$d * \frac{1}{\sqrt{\frac{-h\ sin\theta}{4.9}}} = vcos\theta$

$v = \frac{d}{cos\theta} * \sqrt{\frac{4.9}{-hsin\theta}}$

The v is the final velocity of the weapon, this section demonstrate the formulation of the proposed concept.

4. Result Analysis

This chapter discusses about the different performance parameters for providing the evaluation of the proposed concept. The detailed analysis and their observation are described as:

A. Time Consumption

The time consumption of the proposed data model for estimating the speed and velocity of weapon is computed between initiation of algorithm and the completion of the processing. That is the total time required to complete the analysis of the input image. This can be computed using the following formula:

$time\ consumption = algorithm\ end\ time - start\ time$

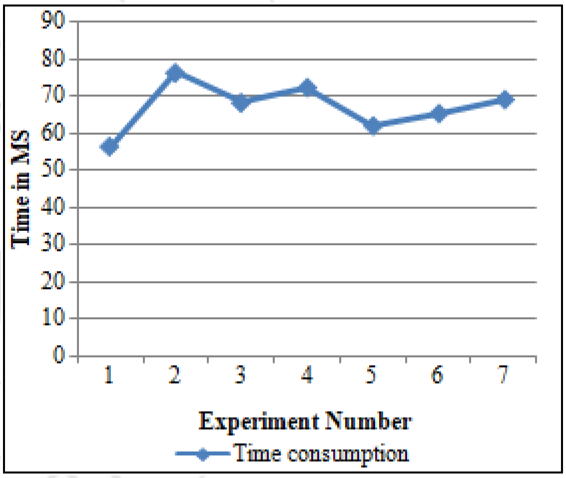

Figure 7: Time Consumption

Table 2: Time Consumption

Experiment Number	Time consumption
1	56.2
2	76.4
3	68.2
4	72.4
5	61.9
6	65.3
7	69.1

Required memory consumption of the proposed technique is described in table 2 and using figure 7. The table contains the different number of experiments performed with the simulation system and the corresponding times required in milliseconds are also reported in next column. Both the parameters are visualized using the figure 7, thus to show the performance X axis includes the experiments and the Y axis shows the time consumption in milliseconds. According to the observation of results the performance of the proposed analytical technique for blood spot analysis is accomplished and consumes a consistent amount of time. In different experiments the time consumption is varies between 56-76 MS.

5. Memory Usages

The amount of main memory required to execute the algorithm or program is denoted here as the memory consumption of the proposed algorithm. The memory consumption of algorithm is computed using the amount of main memory allocated to the process and the amount of memory remain during the execution of the algorithm or process that can be computed using the following formula:

$$\text{memory usage} = \text{total memory} - \text{free memory}$$

Table 3: Memory Usages

Experiment number	Memory in KB
1	24749
2	25544
3	24811
4	25726
5	25184
6	25016
7	24915

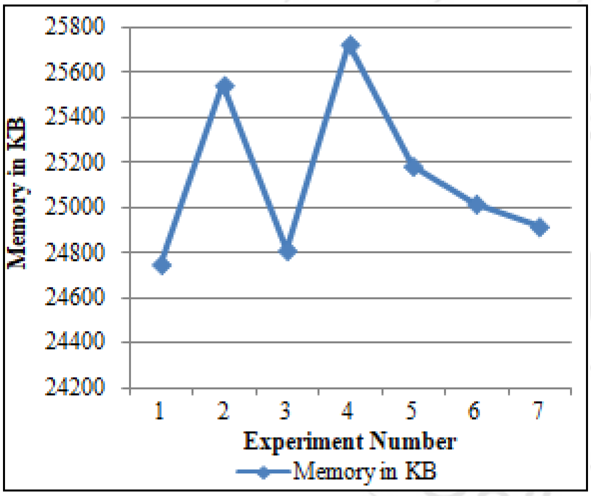

Figure 8: Memory Usages

Table 3 contains the two columns first provides the number of experiments performed with the algorithm and the second column shows the amount of main memory in terms of KB (kilobytes) required for processing the data. The table 3 data is visualize using the figure 8 to represent the performance the X axis of the diagram shows the number of experimentations and the Y axis shows the memory requirements of the algorithm. According to the observations the algorithm demonstrates the limited amount of consumed memory. Additionally that varies between 24700 KB -25750 KB.

6. Conclusion and Future Work

This chapter draws the conclusion of the proposed work and the observations and facts concluded during the experimentation and development. Additionally the future prospect of the proposed technique is also suggested for work.

Conclusion

The Forensic science is the application or a tool of science to criminal investigation. Forensic scientists collect and analyze scientific evidence during investigation. Therefore it is a very essential domain of criminology. The forensic science is also useful for understanding the crime scene and the different other factors about the crime. In this presented work a model for blood splatter analysis is proposed for design and implementation. The blood splatters are the evidence of the crime and it is used to find the information about the weapon and their use. In this presented work the aim is to find the facts about the weapon speed and the angle of operation. Therefore a mathematical model is proposed and implemented.

The proposed technique is basically the combined approach of different areas of science, physics and image processing. Basically the proposed system accepts the blood spot image. Therefore from this image required to discover the edges of the blood spots. For computing the edges of the input image the canny edge detection algorithm is implemented. This algorithm provides the edge information which further edited using the local canvas window by input of line. Using the line input and the actual horizon the angle of spot creation is developed. In further by solving the law of motion equations and trajectory analysis technique the speed of the weapon and the time of the blood traveling is also computed.

The implementation of the proposed approach is provided using the JAVA technology. Additionally for demonstration of performance of the proposed technique the memory usages and time of the image analysis is computed. The table 4 contains the obtained performance of the proposed working model.

Table 4: Performance summary

S. No.	Parameters	Remark
1	Time consumption	The proposed technique is adoptable due to efficient processing of the image it consumes 56-76 MS for producing the output
2	Space complexity	The proposed technique is also suitable and efficient in terms of memory resource consumption it consumes between 24700 KB -25750 KB memory during different experiments

According to the table 4 proposed technique able to process images for extracting the required information which is utilized in crime scene analysis in limited memory and time consumption.

Future Work

The main aim of the proposed work is to investigate the blood splatter trajectory analysis technique and implementation of new approach is accomplished successfully. In near future the following work is suggested for improvements:

The current system directly implemented with the canny edge detection approach suggested comparing more algorithms for edge detection and their smoothing.

The current system designed with the concept of law of motion and the trajectory analysis in future it is suggested to evaluate other available techniques to improve the proposed model.

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