IMAGE ANALYSIS FOR BLOOD SPATTER PROBLEMS

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IMAGE ANALYSIS FOR BLOOD SPATTER PROBLEMS

by

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DECLARATION OF THESIS

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DEDICATION

To my wonderful parents, Dr. Moslemuddin and Dr. Sabira

...who have raised me up and encourage me to be the person I am today

To my beloved Brother, Rifatul Bari

...for all the unconditional love, and support

To my kindest Grand-mom, Kohinur Begum

...in all love, humility, and gratitude

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ABSTRAK

Kejadian jenayah semakin meningkat sejak mutakhir ini. Biasanya dalam kes-kes sebegini, bukti utama jenayah ialah berdasarkan kesan percikan darah. Pakar forensik sedang cuba untuk meramalkan kejadian jenayah setepat yang mungkin berdasarkan bukti kesan percikan darah di tempat kejadian. Hingga kini, banyak program teknologi telah dibangunkan untuk meramalkan kejadian-kejadian jenayah di tempat kejadiannya. Walaubagaimanapun, masih terdapat beberapa kekurangan dalam sistem teknologi yang sedia ada, termasuklah dalam meramalkan punca dan arah percikan kesan darah, kompilasi daripada jumlah input dan juga kekurangan kajian dalam teknik klasifikasi seperti Neural Network (NN) dalam bidang ini. Dalam tesis ini, fokus utama ialah untuk meningkatkan kaedah ramalan secara teori dan praktikal. Kaedah yang dicadangkan dalam tesis ini adalah berdasarkan teori model Hukum Newton untuk percikan darah secara linear dengan menganggap percikan tersebut mengalami seretan. Teknik ini menghasilkan keputusan yang lebih tepat berbanding model yang menggunakan Hukum Stokes, atau yang telah digunakan dalam kajian-kajian yang lepas, iaitu sekiranya radius percikan darah lebih daripada 2mm. Untuk menjalankan kajian eksperimen beberapa imej kesan darah sebagai sumber data diperlukan, namun dalam kajian yang lepas masih menghadapi kekurangan dari segi kecukupan jumlah data. Oleh itu, satu set data dengan 1252 imej kesan percikan darah telah dibangunkan berasaskan formula kesan darah secara sintetik dalam senario percikan darah secara praktikal. Akhir sekali, proses klasifikasi dan automasi untuk pembinaan arah percikan darah menggunakan dua jenis Neural Networks modul iaitu Cascade Forward Neural Network (CFNN) dan Function Fitting Neural Network (FFNN) telah dicadangkan dalam tesis ini. CFNN dan FFNN telah diuji dengan menggunakan set data imej yang dibangunkan. FFNN menghasilkan persembahan ketepatan purata sebanyak 91.1% menggunakan imej kesan darah, yang mana 4.5% lebih tinggi daripada CFNN dan keputusan-keputusan kajian yang lepas. Sistem yang dicadangkan ini boleh membantu para pennyelidik forensik untuk mendapatkan bukti jenayah dengan lebih mudah, cepat dan tepat di masa hadapan.

Image Analysis for Blood Spatter Problems

ABSTRACT

Violent crime scenes are becoming increasingly common nowadays. Usually in such cases, the obvious evidence of the crime is blood spatter. Forensic Specialists try to predict the event of the crime as accurately as possible based on blood spatter evidence in the scene. Recently, programs have also been developed to predict the events in the crime scene. However, there are several shortcomings including predicting the source of origin and trajectory of the blood drop, complications from large amount of manual input and lack of research on related classification methods, such as Neural Network (NN) in this field. In this thesis, focus is given to enhance the prediction method both theoretically and practically. The proposed theoretical model is based on the Newton's Law for linear blood spatter drop in motion, assuming the motion has drag. It produces more accurate results compared to the model using Stokes' Law, which has been used in previous researches, if blood droplet radius is more than 2 mm, otherwise they are comparable. To perform experimental research, a number of available blood stain image data is necessary, but there is no available data. Hence, a database (DB) with 1252 blood stain images has been created through the formation of synthetic blood formula and practical bloodletting crime image scenario. Finally, the classification and automation for the reconstruction of blood droplet trajectory using two different Neural Networks (NN) modules which are Cascade Forward Neural Network (CFNN) and Function Fitting Neural Network (FFNN) is proposed. The CFNN and FFNN then tested with the developed image data-set. FFNN exhibits in average 91.1% classification accuracy for blood stain images, which is 4.5% better than CFNN and significantly better than previous researches. The proposed system may help forensic investigators to acquire crime scene evidence in an easy, faster and reliable way in near future.

CHAPTER 1

INTRODUCTION

1.1 Overview

The practice of using science to gather information about a crime or any other event that needs to be considered as evidence in a legal system is called forensic science or forensics. It plays a vital role in the criminal justice system by providing investigators with scientific information through the analysis of physical evidence. Forensic Science is a multidisciplinary subject, drawing principally from chemistry and biology, but also physics, geology, psychology, social science, etc. (Bevel, 2001; Marriner, 1991). The information gathered must be as vital as possible as a safeguard against erroneous deductions.

One subset of forensics is bloodstain pattern analysis (BPA), which includes gathering information from bloodstains on various surfaces to determine about events that unfurled during a crime scene (Bevel, 2001; Marriner, 1991; Wonder, 2001). The examination of shapes, locations and distribution patterns of bloodstains is required to provide an interpretation of the physical events by which they were created. Based on the premise, all bloodstains and bloodstain patterns are characteristic of the forces that have created them. Bloodstain pattern analysis involves the study of the static consequences (blood splatters) resulting from blood shedding. The analysis focuses on factors such as distribution, size and shape of bloodstains, and location of the spatter. These components, when correctly analysed, can help reconstruct the event that led to the bloodstain. BPA can also help validate or disprove statements provided by suspects, victims, or witnesses. There are various types of patterns, each with a different meaning.

Blood is one among many other objects on Earth whose behaviour conforms to the laws of physics. Bloodstain pattern analysers need to have a very thorough understanding of physics. Blood has many physical properties similar to those of water, but it responds differently to the same external forces due to its different viscosity, adhesion, capillary action, and density. These factors can be translated for proper investigation of crime scenes (Reynolds, 2008; Wonder, 2001).

Once a blood droplet exits the human body, it travels along a unique trajectory toward the surface of impact. This trajectory usually resembles a parabolic path. Besides, while the droplet travels along the parabolic path, radial contractions or oscillations occur (Raymond, 1996). The forces acts on the blood particle are assumed to be gravity and drag forces. The shapes of the stains are projected spheres onto the recipient surface, which are ellipses on planar surfaces. Observers are usually able to observe the impact positions and guess or measure possible impact angles after an event took place. However, they are unsure about the initial blood emitting position along with the trajectory travelled by a blood droplet in air during the event, which is very important to be investigated and found and this is the focus of this research. Besides, measuring more accurate blood droplet size, impact angle and direction has been also taken into account.

1.2 Motivation and Problem Statement

Usually, forensic blood analysts go through years of training to gain proper experience for crime investigation. The methods which are used by such specialist are time consuming and degrading of the evidence may happen due to this delay (Rossmo, 2008; Bevel & Gardner, 2002). In this thesis, automation of a part of the processes is being carried out to improve analysis of blood spatters. In doing so, experts could have more support in their analysis. The motivation behind this research is to reduce delay and improve data analysis of blood spatter image (found in crime scenes) using theoretical analysis and artificial intelligence. This research attempts to automate the procedure of linear blood spatter analysis given the images of a crime scene.

General practice to identify the position and angle of impact of a bloodstain, the investigators assumed that blood droplets travel in a straight line (Wonder, 2001). To travel in a straight line, the blood particles must travel at a high enough velocity, which does not occur in reality. One of the most common methods applying this assumption is the String Method (Bevel, 2001). This method is suitable for small size blood droplet (like mist) which occurs as a result of gun spattering, but not for medium and moderately larger blood droplet size. Moreover, String Method is manual and leads to some degree of error for investigation due to limitations in human measurements.

In the trajectory of an object travelling through the air, the only forces working on the object are gravity and drag. The gravity of an object moving through the air is approximately fixed, however the drag force may change according to the size, shape and velocity of the said object. This is true for blood particles traveling through air medium as well. Hence, the blood droplet behavior depends on the particle's Reynold number, $R_e = \frac{\rho v d}{\mu}$, where, *v*: velocity of particle, *d*: diameter of the particle, ρ : density of fluid/air (ρ = 1.225 kg/m^3 for air, and ρ = 1060 kg/m^3 (Cecchetto & Heidrich, 2011) for real human blood), and μ : viscosity of fluid/air (for air 1.78×10^{-5} *kg/m.s*, as blood particle fly through air in this case). Usually, Stokes' law applies for a small solid particle with Reynolds number less than 1.0 or less than 1000 which produce the drag coefficient

$C_D = \frac{24}{R_e}\ or\ \frac{24}{R_e}\,(1 + \frac{R_e^{\frac{2}{3}}}{6})$ respectively (Reynolds, 2008). Besides, the Newtons drag coefficient can be found as, $C_D \cong 0.44$ for Reynolds number greater than 1000.

In previous researches, researchers have either assumed that there is no drag or attempted to use Stokes' Law (Cecchetto & Heidrich, 2011) to calculate the drag of blood droplets for all cases and to find the reconstructed flight path as it moves through the air (in this case, Re << 1000). But Stokes' Law for drag is only applicable for blood droplets with very small in size and high velocity (mist like droplets with Reynold's number, Re << 1000). However, it is not suitable for blood droplets with medium and/or relatively large droplet size respectively with relatively low velocity (Popendorf, 2006), which is the usual case for most of the crime scenes. For law of motion in physics, usually Newton's law is used for calculating drag of relatively large size (with Re>1000) particle travelling through air (Croce, 2005; K. C. Wilson, 2006). It is also apparent from the Re formula that for even blood droplet diameter, d = 0.002 mm with a velocity v = 0.01 m/sec produce a value of $R_e = \frac{(1060)x(0.01)x(0.002)}{1.78x10^{-5}} = 1191.01$. Influenced by this phenomenon, theoretical model using Newton's law has been investigated in this research to verify its suitability for various blood droplet sizes. Then combination of both Stokes' and Newton's law is then proposed to be used as per need.

Over the last few decades, image processing techniques have been developed tremendously. In computer science and electronic engineering, image processing is a process in which the input is an image, acquired from pictures or frames of video and the output can be either an image or a set of characteristics (or properties/ parameters/ features) related to the input image. Blood stain is the evidence of any violent crime scene. The blood stain image plays a vital role to provide an interpretation of the physical events. Hence, they should be collected and documented for reliable feature extraction and pattern analysis. To perform related research, a number of available blood stain image data is necessary in public domain. So far, some visible and thermal image data sets are available on pedestrians and/or medical applications for various detection and monitoring purposes (CVonline, 2011; Johnson & Becker, 1999; Sudeb et al., 2013), but no blood stain images. Hence, here, focus is given to create some crime scenario using synthetic blood (Millington, 2012) and develop a small-scale blood stain image database (DB) for practical investigation towards automated investigation process. The developed database will be made available for researchers in this area.

Automation related research includes computer aided design (CAD) using BacktrackTM (Pace, 2006) is a software developed to compute impact angle of bloodstains. However, the bloodstains sizes still have to be manually measured and outlined by following the similar process like String Method (Bevel, 2001). Actually, BacktrackTM (Pace, 2006) works based on extended String Method (Bevel, 2001), which leads to a combination of partly manual and partly automated method. As a result manual calculation error due to human limitation cannot be avoided. Here, the method to calculate the trajectory is also calculation based. Hence, demands towards an advantageous automated system. The research in (Shen et al., 2006) attempted to develop an automatic process, but the algorithm was complex and the error was fairly high. Though, research has been done to automate bloodstain image processing purposes, to the best of author's knowledge, so far artificial intelligence has not been used yet. The automation process is targeted to be done here using artificial Neural Network (NN), which may receive blood stain images as input and produce output in terms of impact angle, direction, source of origin and air flight trajectory of the spatter.

1.3 Aims and Objectives

The aim of this research is to develop an automated linear bloodstain image analysis prototype using neural network for crime scene investigation. To achieve the aim, the objectives of the research are:

1. To develop a theoretical model for analyzing the free-flight blood droplet (Re >= 1000) trajectory through air using Newton's Law, then to propose an algorithm to analyze the trajectory for all blood droplet sizes (both Re >=1000 and Re < 1000).

2. To construct a blood-stain image database and a prototype model using Neural Network to auto-analyze the stains in order to obtain their sizes, outlines, impact angles, directions, and air-flight trajectories practically based on impact image of blood droplet. Then to reconstruct the area of origin based on the position and directions of impact stains.

3. To verify the performances of the prototype for smooth workability, compare with theoretical performances and related works.

1.4 Brief Methodology

This research is divided into four phases as:

Phase 1: The first part is the analysis phase. In this phase the forces acting on a spherical blood droplet moving freely through air is analyzed with following assumptions:

(i) First: No force acts on the blood droplet except gravity.

(ii) Second: Besides gravity force, drag force also acts on droplet.

Based on droplet size (diameter, d), the Reynolds number (Re) can be determined. The drag force is classified into two regions as:

a. If Re > 1000, Newton's Law of region drag force is considered to be worked on the droplet and a noble theoretical model is develop.

b. If, Re < 1000, Stokes' Law of region drag force works on the droplet. The derivation is done to realize the steps and for comparison.

Phase 2 (a): In this phase, the experiments were carried out to create image data set for experimentation. At first materials were investigated and used to create synthetic blood, close to the density of real blood as much as possible. Then using created synthetic blood, experiments were carried out to see the suitability of blood in certain situations. An Image-Set is created including all the images and its features. A group of image data is divided into three sets as:

(i) Group 1: Training data set to train the NN module.

(ii) Group 2: Test data set to test and efficiency and estimate the error of NN module and the prototype.

(iii) Group 3: Validation data set to validate the final model.

Phase 2 (b): In this phase, an automated prototype for crime image investigation is developed in MATLAB by considering the following:

(i) Efficient image preprocessing (combining the existing methods) tool identification to detect the edges and shapes based on impact image of blood droplet.

(ii) Develop a suitable neural network (NN) module for image classification and feature extraction (e.g., impact angle, direction, etc., practically) based on input in (i).

(iii) Then to reconstruct the area of origin for blood droplets based on the obtained position and directions of impact stains in (ii).

Phase 3: The last phase is to test the prototype model followed by collect and compare the performances data. Then validate the prototype model.

The brief methodology followed in this research is also presented in terms of self-explanatory diagram in Figure 1.1.

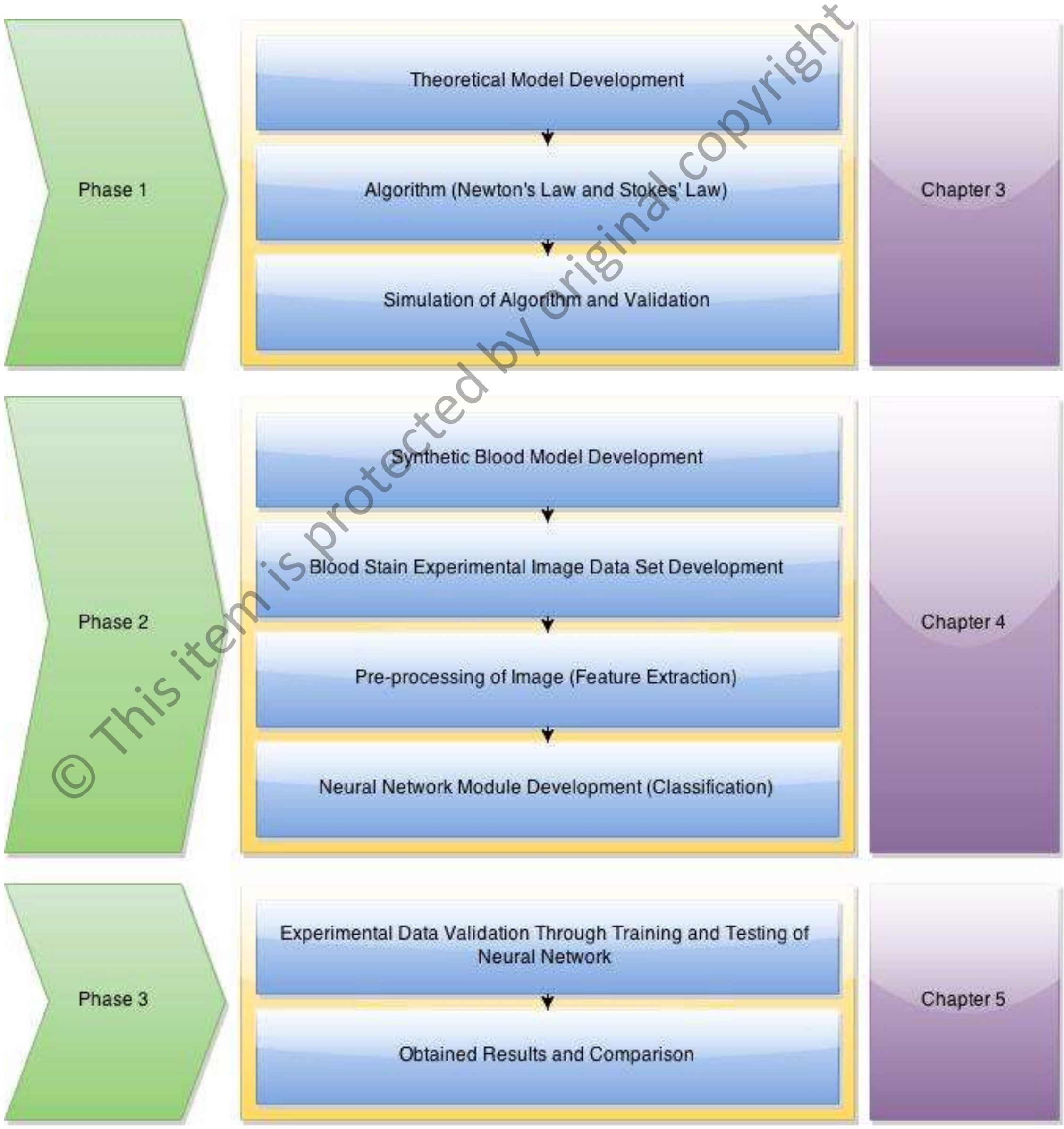

Figure 1.1: The Pertained Brief Methodology Diagram.

1.5 Research Scope

This research analyses the blood stains and returns the impact angle, direction, size and point of origin. To achieve this, first analysis of the reconstruction equation has been carried out using Stokes' law of motion. This equation is then improved to get better results using Newton's law of motion. Followed by, their combination for various blood droplet sizes and velocity. Then, experimentation has been done to create fake blood and acquire a dataset of bloodstains images.

In this thesis, simple feature extractions are used to find image properties. A combination of normalization, edge detection, thresholding and filling up holes is used for image localization. The recognition problem is subdivided into four parts, which are: Image acquisition, pre-processing the image, image segmentation and feature extraction.

After feature extraction has been carried out, the extracted features were fed into the developed Artificial Neural Network (ANN) module. ANN is relatively crude electronic models based on the neuron structure of the brain (Carpenter, 1992). In this research, neural network (NN) feature classification is used to analyze and process the extracted features. The net is then trained to recognize the input images into the system. The NN outputs values are used to read the blood stain features for reliable investigation. This is realized as the system automation using Artificial Neural Network (ANN) in Matlab based environment.

1.6 Study Module

The study module of this research by showing how it is formulated from a wide area of choices to the specific objectives is shown in Figure 1.2.

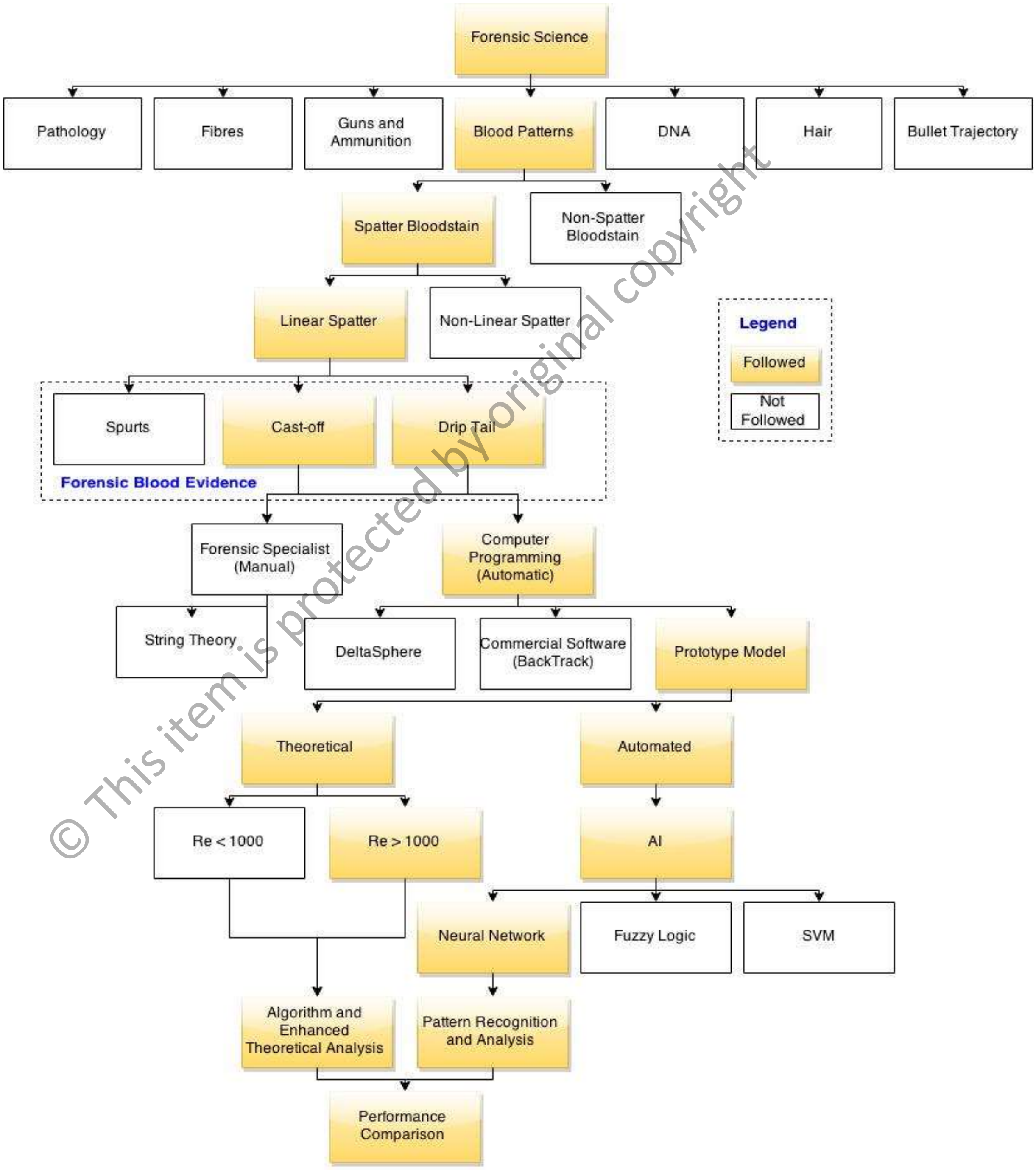

Figure 1.2: The Study Module of the Research