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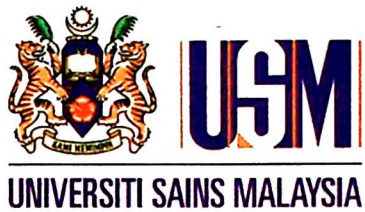

FORENSIC ENHANCEMENT OF SHOE PRINT IMAGES USING ADOBE® PHOTOSHOP®

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE DEGREE OF BACHELOR OF SCIENCE (HONS) IN FORENSIC SCIENCE

SARAH ALIAH BINTI AMIR SARIFUDIN

SCHOOL OF HEALTH SCIENCES

UNIVERSITI SAINS MALAYSIA

HEALTH CAMPUS

16150 KUBANG KERIAN, KELANTAN

2015

In the name of Allah, the Most Glorious, the Merciful

For Aki

Thank you…

May Allah grant him peace.

May Allah make him among those who are blessed in Jannah.

ACKNOWLEDGEMENT

Praise be to Allah, the creator of all the creations, who is eternal and exists without a place, we ask Allah to raise the rank of Prophet Muhammad and his kind companions.

A very big thanks to my supervisor and academic advisor, Dr. Ahmad Fahmi Lim Abdullah for his guidance from the beginning of this study till the end and for his support on my academic development throughout these four years of undergraduate studies. I would like to thank Dr. Dzulkiflee Ismail, my examiner and Dr. Nur Haslindawaty Abd Rashid, the course coordinator for the final year project.

Also to thank all the academic and non-academic staff at the School of Health Sciences, especially from the Forensic Science programme for their willingness to assist in the study and all through my undergraduate degree. I would like to extend my gratitude towards Universiti Sains Malaysia and Ministry of Education for the financial support through RU grant [1001/PELECT/814105] and PRGS grant [203/PELECT/6740017].

Most especially, I wish to thank my parents, Puan Nornai'lah Abdul Latiff and Encik Amir Sarifudin Mansor for their love, encouragement and support, and most importantly their faith in me. You are my inspiration. Last but not least to my friends, near and far, thank you for your help and encouragement.

Did He not find thee wandering and direct (thee) - Surah Ad-Dhuha 93.7

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ABSTRACT

Recovery of shoe prints at crime scenes provides useful information in investigation and act as valuable evidence of the crime. Unfortunately, most shoe print evidence are placed aside due to the poor state of the evidence, absence of comparison samples, and the lacking of knowledge and exposure towards such evidence. Many recovered shoe prints at crime scenes are in low quality which contribute in the difficulties of identification and comparison processes. Preservation and digital forensic enhancement of shoe print images are essential in providing an increase of the evidential value of such prints. The study builds on the utilisation of commercially available image processing software Adobe® Photoshop® CC for the forensic enhancement of shoe print images. Several shoe print images made on different surfaces i.e. newspaper, rubber mat and carpets; were photographed using a Canon EOS 40D Digital Single Lens Reflect (DSLR) camera. These shoe prints were created using black ink stamp pad. The enhancement of the shoe print images were performed using the Adobe® Photoshop® CC adjustment and filter tools which include white balance, colour adjustment, and sharpen filters. The shoe print images were successfully enhanced by either fully or partial reduction of the noise background to contrast the prints from their backgrounds. The isolation of the shoe prints from the backgrounds has improved the clarity of the shoe prints and therefore aid in further comparison and identification analysis.

ABSTRAK

Pengumpulan kesan tapak kasut di tempat kejadian memberi informasi dalam penyiasatan kes dan boleh dijadikan sebagai keterangan bahan bukti terhadap jenayah yang dilakukan. Namun, kebanyakan bahan bukti kesan tapak kasut diketepikan kerana keadaan bahan bukti yang tidak sempurna, kekurangan sampel perbandingan, dan kurangnya pengetahuan dan pendedahan terhadap bahan bukti tersebut. Kesan tapak kasut yang dijumpai di tempat kejadian yang berkualiti rendah telah menyumbang kepada kesukaran dalam proses pengenalpastian dan perbandingan kesan tapak kasut. Pemeliharaan bahan bukti dan penambahan kualiti imej kesan tapak kasut secara digital adalah penting dalam meningkatkan nilai keterangan kesan tapak kasut tersebut. Kajian ini adalah berasaskan daripada penggunaan perisian pemprosesan imej Adobe® Photoshop® CC yang boleh didapati secara komersial untuk penambahan kualiti dan nilai imej kesan tapak kasut secara forensik. Beberapa imej kesan tapak kasut di atas permukaan yang berbeza iaitu surat akhbar, tikar getah dan permaidani telah diambil dengan menggunakan kamera *Digital Single Lens Reflect* (DSLR) Canon EOS 40D. Kesan tapak kasut ini dibuat dengan menggunakan dakwat cap berwarna hitam. Penambahan kualiti dan nilai kesan tapak kasut telah dilakukan menggunakan teknik-teknik yang terdapat dalam perisian Adobe® Photoshop® CC seperti penyelarasan *white balance*, warna, dan penapis penajaman imej. Imej-imej kesan tapak kasut telah berjaya ditambah kualiti dan nilai dengan pengurangan latar belakang imej secara keseluruhan atau sebahagiannya. Hal ini telah membolehkan pengasingan kesan tapak kasut daripada latar belakang imej untuk analisis pengenalpastian dan perbandingan kesan tapak kasut.

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Foot prints and shoe prints that are found at the crime scene often provide reliable and valuable evidence of the presence of an individual (Bodziak, 2000). These prints act as constructive evidence of the cases based on the nature of the prints. Foot and shoe prints (or impressions) are great sources of evidence due to the frequency of the prints found at the crime scene, durability and the aging of the prints, positive identification of known and unknown prints, and various information provided by the foot and shoe prints (Bodziak, 2000).

Shoe prints are found more common when compared with the foot prints in the surroundings. This may due to the present period of time that almost everyone possess at least a pair of footwear. This also leads to a number of companies and government sectors in building up shoe prints databases based on the manufacturers, types of footwear, pattern, and size.

However, foot print and shoe print evidence are commonly neglected due to the limited knowledge of both the investigators and the court of law (Bodziak, 2000). Many enhancement methods have been developed to assist the collection and preservation of the foot and shoe prints evidence in order to maintain the state of the originality of the evidence. The enhancement methods would provide higher probability for the prints to stand as valuable evidence in the court of law.

1.2 Introduction

Foot prints and shoe prints are commonly being left on the ground or other surfaces when a person steps and walks. It is a normal unconscious act for everyone. In forensic aspect, these prints are one of the most common physical evidence found in crime scenes and present more frequently than fingerprints (Srihari, 2013). Evidence provided by a positively identified print is as strong as the evidence from fingerprints, tool marks, and typewritten impressions (Srihari, 2013). Such evidence is considered as important and treated in similar manner as the fingerprint and DNA evidence by the investigators and forensic scientists (AlGarni and Hamiane, 2008).

Foot prints are the marks made by the sole of the foot (or feet), while shoe prints are the marks made by the outside surface of the sole of a shoe. Footwear prints are the prints made by any types of footwear including slippers, boots, sandals, and shoes. The terms "footwear prints" and "shoe prints" are consecutively being used in the forensic community; and referred to the same type of evidence. In this study, the terms "shoe prints" are used in reference to the object of the study.

Shoe prints can be classified in several manner. First, shoe prints can be categorised as two dimensional and three dimensional. Two dimensional prints possess length and width, whereas the three dimensional prints have the additional information on the depth. Secondly, shoe prints can be categorised based on their appearances. Shoe prints can either form as patent and latent prints. Patent prints are prints that can be observed without any enhancement techniques, while latent prints can only be seen and developed using suitable enhancement techniques.

The enhancement techniques used in forensic help to preserve such prints, and aid in the collection of evidence. There are many methods to preserve and collect shoe prints evidence such as photography, traditional brush and powder method, chemical methods, Electrostatic Print Lifter Apparatus (ESLA) and casting.

Examination of shoe prints have been conducted since the end of the 18th century (Johansson and Stattin, 2008). Analysis of shoe prints may provide information on the shoes and the wearer (Johansson and Stattin, 2008). According to AlGarni and Hamiane (2008), shoe prints comparison and identification can be described based on the geometric patterns such as triangle shapes, zigzag patterns, and the brand's logo by human expert. Additionally, it is a common practice for forensic investigators to conduct manual comparison and identification of prints by classifying the prints based on a number of patterns (AlGarni and Hamiane, 2008).

Since visual comparison of prints is bound to human error (Kerstholt *et al.*, 2007), researchers have studied automated computer system for the purpose of matching the known and unknown shoe prints. Such studies on automated shoe print identification is still relevant and have not been broadly reported (AlGarni and Hamiane, 2008). In recent years, many studies have been conducted to develop shoe print database for semi-automated and automated footwear comparison methods. Some of the examples of shoe print databases are SICAR®, Forensic Science Services (UK), TreadMark™, and SoleMate.

As mentioned earlier, there are various methods to preserve and collect shoe prints evidence and one of the methods is photography. Photography is the most common method of preserving any shoe prints. It is the general protocol of crime scene management (Srihari, 2013). It is important to preserve shoe prints as the prints and marks may be damaged by some enhancement and preservation methods (Ashe *et al.*, 2000). Similar to fingerprint identification, shoe print identification can be conducted based on the print image quality (Khalefa *et al.*, 2011).

Comparison and identification of shoe prints based on their image qualities have the potential to reduce the use of chemicals techniques (Miskelly and Wagner, 2005) and avoiding any damages by some of the enhancement methods and handling (Ashe *et al.*, 2000). The image of print is usually masked by the backgrounds. This makes it difficult for extracting key components from the evidence (Wenner and Petranek, 2004). The techniques like local histogramme equalisation, colour adjustment and filters in photography processing software aid in improving the clarity and identifies the corrupted regions of the image (Nigam and Mishra, 2011). The images could become well-defined for the purpose of classification, identification and preservation.

Adobe® Photoshop® is a type of image processing software that is suitable for such photographic enhancement due to the capability of the software to create layers of the image. The base layer is created at the beginning from the original image, while adjustment and enhancement are produced on separate layers. It provides a non-destructive method in improving the visual of the evidence to allow further forensic examination. In this study, photographic method is used to preserve the shoe prints

and enhancement techniques applied using commercially available image processing software, Adobe® Photoshop® CC are carried out to improve the image quality of the prints.

1.3 Significance of the Study

Photographing the crime scene can be challenging due to several factors such as the lighting, surrounding areas, and the weather. Hence, photographs taken at the crime scene may not be produced at the optimal parameters (Baron, 2008). Although, the crime scene investigation teams have qualified photographers, the environment factors could limit the attempt in producing good quality image of the photographs. In the recent standard operating procedure (SOP) of any crime scene management, digital cameras are being used to document the crime scene in exchange with the film cameras. The usage of digital cameras may help in imaging repair of the photographs taken in the less-than-ideal situations (Baron, 2008).

Digital photography is admissible as evidence when the SOP is followed; while suitable image processing software is required to process the photograph. Some software may consist of secured asset management of the photos in maintaining the chain of custody of the evidence. There are many image processing software available commercially for enhancing forensic details. This study uses the Adobe® Photoshop® CC to enhance the shoe print images taken by a digital single lens reflect (DSLR) camera.

Adobe® Photoshop® CC is being used in this study for several reasons. First, Adobe® Photoshop® CC is commercially available and it functions similar to other image processing software such as the Ocean System™'s ClearID® (Baron, 2008). Additionally, the Adobe® Photoshop® CC consists of the latest image adjustment tools, filters, repair and restoration techniques for image enhancement (Adobe System Incorporated, 2015).

By using the Adobe® Photoshop® CC, unclear print images on different background may be enhanced without altering the details of the print. Besides, enhancement can be done on the print images regardless the types of substances used to produce the shoe print. Adobe® Photoshop® helps in processing high number of photographic evidence from crime scenes, hence shorten the time of evidence identification process (Adobe System Incorporated, 2015).

1.4 Objectives of the Study

The study comprised of two objectives namely:

i. To investigate the enhancement techniques on shoe print images.

ii. To enhance unclear shoe print images using commercially available image processing software, Adobe® Photoshop® CC.

1.5 General Approach of the Study

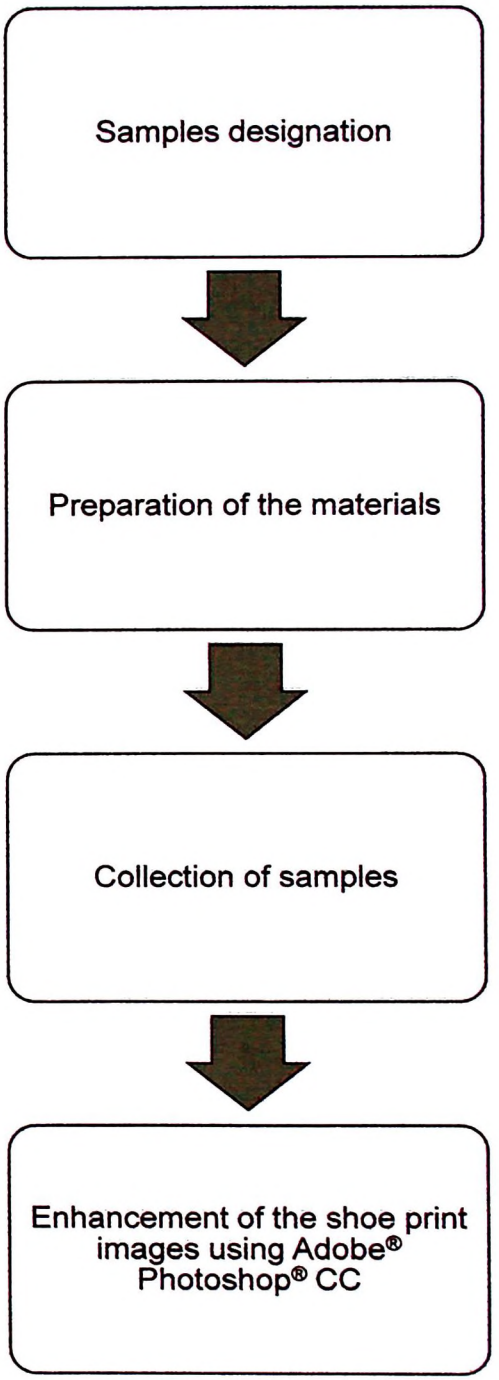

Figure 1: The general approach of the study

CHAPTER 2: LITERATURE REVIEW

2.1 Terminology

There are several terms that have been used to describe the shoe print evidence i.e. shoe print, shoe impression, footwear print, and footwear impression. These terms have been widely used by the forensic scientists, investigators, law enforcement agencies, lawyers, in news, and also by the general public. These terms are interchangeable and acceptable in the court of law. Section 2.1.1 describes the definitions and usage of the terms used in describing the shoe print evidence.

2.1.1 Differences between the Terms 'Shoe' and 'Footwear'

The terms 'shoe' and 'footwear' have been used alternately in forensic investigation. Shoe is defined as an outer cover of the foot which has a hard layer at its bottom called a sole and an upper part that covers the top of the foot (Merriam-Webster Incorporated, 2015b). Footwear is more general, and defined as *"any types of apparel worn on the feet"* (SWGTREAD, 2013; Merriam-Webster Incorporated, 2015a) for examples shoes, boots, sandals, slippers, and high heels.

Literature has established equal usage of these terms (Bodziak, 2000; SWGTREAD, 2006; Johansson and Stattin, 2008; Hancock *et al.*, 2012; SWGTREAD, 2013; Benedict *et al.*, 2014). Apart from that, many law enforcement agencies such as the Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD), National Institute of Justice (NIJ), International Association for Property and Evidence Inc. (IAPE), and Federal Bureau

Investigation (FBI) use both terms in their forensic guidelines (Held, 2001; International Association for Property and Evidence Inc, 2005; Bowen and Schneider, 2007; SWGTREAD, 2013). This study uses the term 'shoe print' based on the sample used i.e. prints of one sport shoe (right side).

2.2 Class and Individual Characteristics

Prior research by Srihari (2011) stated that any specific model of shoe will be owned by a small fraction of the general population due to the variety of shoes available on the market. Most of these shoes have distinctive outsole patterns, which may present on different brands and models. If the outsole pattern of a shoe can be determined from its marking, this can significantly narrow the search for a particular owner of the shoe. The identification of any unknown shoes and the owners are based on the pattern characteristics i.e. class and individual characteristics of the prints created by the shoes. Detail retained in a shoe print may be insufficient to uniquely identify an individual shoe (Wisconsin Department of Justice, 2013) but is still very valuable.

2.2.1 Class Characteristics

Class characteristics are physical characters shared by a group of similar objects or persons (U.S. Fish & Wildlife Service National Forensics Laboratory, 2010). Class characteristics of a shoe print can determine the size and the brand of the shoe. Yet, these information can only narrow down the owner of the print into a group of people (Wisconsin Department of Justice, 2013). In order to acquire the sole owner of the shoe print, one needs to examine the individual characteristics of the impressions.

2.2.2 Individual Characteristics

Individual characteristics are physical characteristics that individually unique (U.S. Fish & Wildlife Service National Forensics Laboratory, 2010). Individual characteristics can help individualisation process of identification of an unknown shoe (Evett *et al.*, 1998). Individual characteristics can point to the identity or the origin. Such characteristics of a shoe print include the wear and tear defects, accidental damages, and/or any irregular points on the prints (Evett *et al.*, 1998). The wear and tear defects are very unique and would not appear on any other prints. Moreover, these defects can indicate the way a person walks, such as putting pressure at one side of the shoe, or at the front portion (Facey *et al.*, 1992). Both characteristics are very useful for comparison purposes. All of these characteristics need to be photographed (manually or digitally) for further investigation and subsequent analysis.

2.3 Digital Evidence (Digital Photograph)

Digital evidence is a type of evidence which store information in binary file format which might be introduced and relied on in court proceedings (Office of Justice Programs, 2010). A binary file format is computer file format that is not in text format (Webopedia, 2015). Such format includes images, media, compiled programs and compressed files (Microsoft, 2011). Digital evidence can be found on electronic devices such as a computer hard drive, mobile phone, CD or DVD, and flash card of digital camera (Mukasey *et al.*, 2001).

Digital evidence include digital photography, videos, files and data. Digital photography is a photographic method which store images digitally for later reproduction (The Free Dctionary by Farlex, 2015). Digital photography is commonly used to document the crime scenes in replace with the analogue photography. Shoe print images are classified as digital evidence when the images are captured using digital cameras. These images are then stored in electronic storage media for further inspection and analysis.

2.4 Digital Chain of Custody

According to Baron (2008), crime scene photographs (both digital and analogue) are usually treated as physical evidence as the information provided by the photographic evidence can link the evidence present at the crime scene. An SOP and valid forensic methods need to be followed in order for the digital photographic evidence to be admissible in the court of law (Reis, 2007). The SOP includes every details and guideline in documentation and storage of the photographic evidence (SWGTREAD, 2006), while any forensic methods that have been used must be repeatable with similar results (Reis, 2007).

The common SOPs include the documentation of how the images are created, transferred, stored, and the person responsible with them (example, the photographer in charge) (Baron, 2008; Pasoh, 2014). If the images are altered, the officer needs to state the reasons for the alteration and how the images are being altered (Baron, 2008). If the images are required to be processed i.e. enhancement process, any handwritten note, a text file or data that contains editing information must to be stored within the file itself (Reis, 2007). For example, if the enhancement process is carried out using Adobe® Photoshop® software, the history log should be activated to store the adjustment information (Reis, 2007).

Besides that, the images have to be stored in removable storage media that cannot be altered or edited by other individuals such as Compact Disc-Recordable (CD-R) and DVD-R. The images cannot be stored in rewritable storage media such as CD-RW, DVD-RW or any portable devices i.e. USB flash drive or external hard disk (Pasoh, 2014).

2.5 Types of Digital Enhancement Methods

There are various forensic digital imaging tools available for enhancement of fingerprints and/or other prints which do not alter the original state of the prints (Nigam and Mishra, 2011). Most of digital enhancement analyses involve the control and application of adjustments and filters tools such as histogramme equalisation, colour adjustments and sharpen filters (Nigam and Mishra, 2011). Previous research have shown the successful enhancement of prints using the Fourier transform with additional methods.

Facey *et al.* (1992) have extracted information from shoe print images using the Fourier transform and pedobarograph (PBG). Pedobarograph is a device which measure the pressure of a foot at different parts of the foot (Kumar *et al.*, 2006). The research emphasised on the wear and tear marks, outlines of the wear patterns, and the distribution of pressure between the foot and ground from shoe mark images (Facey *et al.*, 1992). In a more recent research, Khalefa *et al.* (2011) have developed enhanced Metre method for directional image processing to work together with the Fourier transform for enhancement of fingerprints. These researchers conducted enhancement techniques by the usage of block filtering, histogramme equalisation and high-pass filtering.

Besides the Fourier transform, many novel research are now focused on the availability of image processing software such as the Photoshop®. For instance, a study by Nigam and Mishra (2011) utilised the commercially available image processing software Adobe® Photoshop® for the enhancement of scanned fingerprints. This study was carried out to improve the appearance of the fingerprints

for minutia extraction algorithms.

As other researchers have studied, prints i.e. fingerprints and shoe prints can be digitally treated and enhanced using Adobe® Photoshop® and its plugins such as Fovea Pro 3 (Miskelly and Wagner, 2005) and ClearID® (Reis, 2007). Moreover, Adobe® Photoshop® aids in the correction of shoe print images deliberately taken at certain angles in determining their evidential values (Shor *et al.*, 2006). These show Photoshop® has numerous potential applications in forensic science.

2.6 Adobe® Photoshop® CC

Adobe® Photoshop® is an image editing software which is commercially available. The latest version of this software is the version CC which had been introduced since 2014. Adobe® Photoshop® is user-friendly due to the availability of tutorials and user guides of the image editing software by the developer and also from the public.

Photoshop® is used when editing of images are required as the software is built up with all the basic and advanced image editing tools (Adobe System Incorporated, 2015). Photoshop® can be used combine different image, transparent overlays, removing objects, and retouching flaws (Adobe System Incorporated, 2015). Adobe® Photoshop® requires Intel® Pentium® 4 or AMD Athlon® 64 processor, with Microsoft® Windows® 7 with Service Pack 1, Windows® 8, or Windows® 8.1; and 2 GB of RAM (Adobe System Incorporated, 2015).

There are many features in the Photoshop® which make it suitable for forensic work. First is the Adobe® Photoshop® has a feature known as Adobe® Camera Raw. The Adobe® Camera Raw software helps in importing and adjustment of the raw file without changing the original camera raw data (Reis, 2007). This is because any adjustments on the raw file are written in separate file (Reis, 2007). Raw file is preferred than other file formats in photographing fingerprints, shoe prints, and blood splatter which may require suitable image enhancement analysis (Reis, 2007).

The second useful feature in relation to forensic application is the history log. This history log is essential to maintain the chain of custody of any cases. The history log of every adjustment using the Photoshop® can be saved automatically. The history log can be saved to the metadata of the image, text file or both (Reis, 2007).

Additionally, specific workflow option based on adjustment analysis can be created using Adobe® Photoshop® (Adobe System Incorporated, 2015) rendering it a useful forensic tool. Numerous tools and adjustments can be selected for the workflow option depending the types of image analysis. For example, the workflow option for fingerprint analysis includes the zoom tool, hand tool, white balance, colour sampler, image adjustment setting, rotation tool and delete button (Reis, 2007). Any additional image adjustments can be done if necessary based on specific images.

Image adjustments can be carried out using Adobe® Photoshop® without altering the original image, either from the raw file format or other file formats available (Adobe System Incorporated, 2015). The adjustments are non-destructive as each adjustment process is layered; hence the process would not be disrupting the layer before it (Reis, 2007). Besides, each layer can be observed separately if required. Other than that, overlays can be created using the software in order to observe different images at the same time or by overlaying two images to investigate the similarities and differences of the images (Adobe System Incorporated, 2015).

CHAPTER 3: METHODOLOGY

3.1 Materials and Methods

This methodology section is divided into several parts. Firstly, it is comprises of the materials, instruments and software used in conducting the enhancement process of the shoe print images follow by methods and analysis of the images.

3.2 Materials

i. A pair of used shoes (Power®, UK size 6)

ii. White A4 paper (Indah Kiat IK™ Yellow Multifunction Business Paper A4 Paper, 80 gsm, extra bright, UOS Corporation Sdn. Bhd., Malaysia)

iii. Newspapers

iv. Two carpets of different colours

v. A multi-coloured rubber mat

vi. Artline® black stamp pad ink (Shachihata Inc., United Kingdom)

vii. Paint brush

3.3 Instruments

i. Canon EOS 40D digital Single Lens Reflect (SLR) camera with a Canon macro lens EF 100 mm USM (Canon, Japan).

ii. Windows® 8.1 Pro Microsoft® Surface™ Pro 1 with 64-bit Operating system, x64-based processor (Microsoft Corporation, United States of America).

3.4 Software

i. Adobe® Photoshop® CC (Adobe Systems Incorporated, United States of America)

3.5 Methods

3.5.1 Sample Preparation and Collection

A pair of sport shoes was obtained for the experiment. The right side of the shoe was chosen to produce shoe print. The same right side of the shoe was used to make all the prints to obtain the same pattern of the outsole. This to ensure the collection of the samples was repeatable.

i. Marking on the outsole of the shoe

One small marking was purposely placed on the outsole of the shoe to create distinctive individual marks. The mark (labelled as 'a') as shown in Figure 2 was created by cutting the outsole using a paper knife.

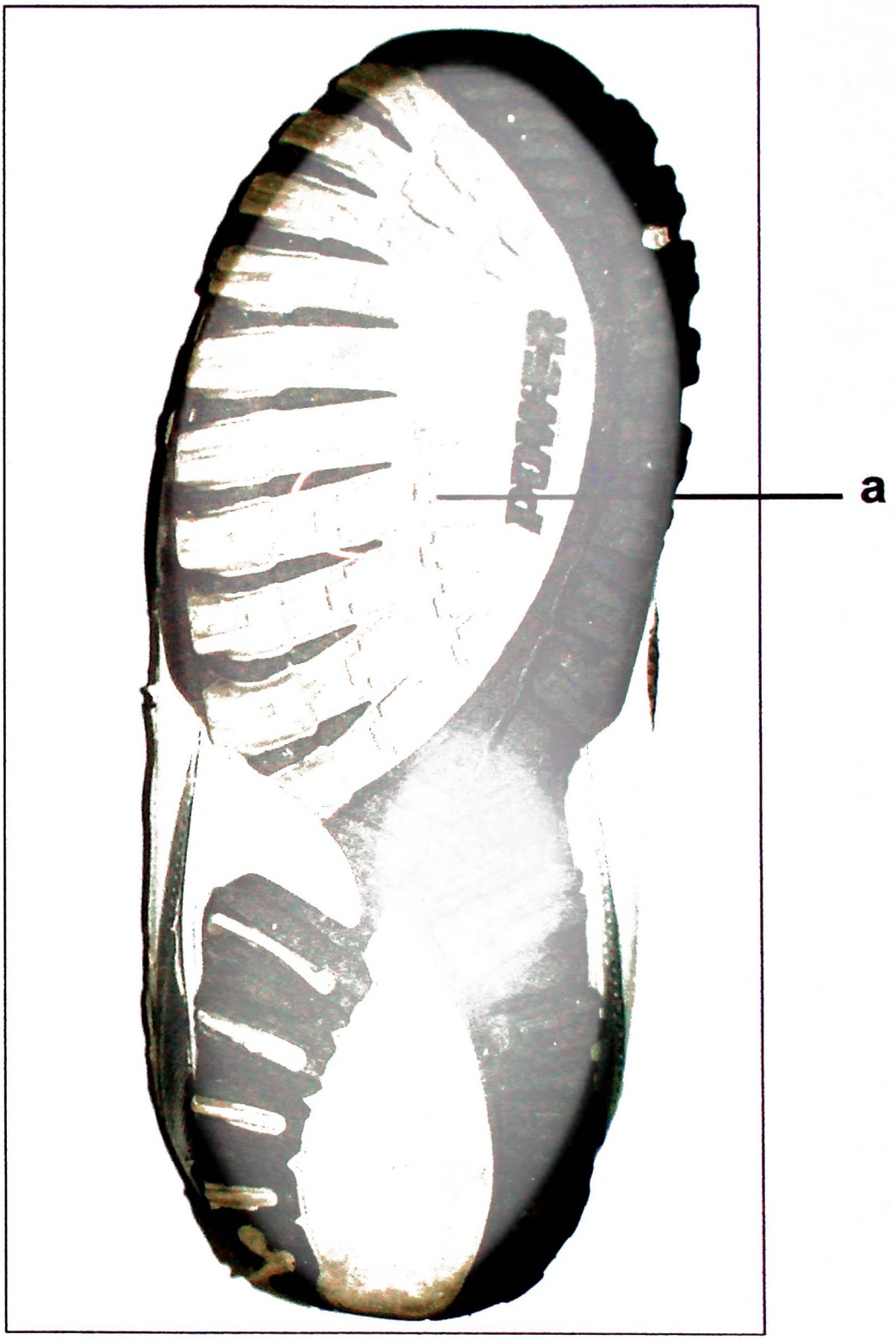

Figure 2: The outsole of the right side of the shoe and the cut purposely created using a paper knife is marked "a"

ii. Selection of ink

The shoe print was first produced using the thumb print set which includes of a tube of thumb print ink and a roller. It was found that it was not suitable to use the ink in producing shoe prints of a sport shoe on multiple surfaces. This is because the thumb print ink was too viscous to be rolled onto the outsole of the shoe. Besides that, it takes longer time for the ink to dry. As the ink was viscous, it is difficult for the ink to be removed from the outsole, causing the ink to be deposited in larger quantity and thicker layer on the outsole of the shoe. This unfortunately caused uneven deposition of the ink for the production of new print on a new surface.

As an alternative solution, the shoe prints were created by painting the outsole of the shoe with black stamp pad ink. Paint brush was used to ensure even contact of ink on the outsole. Transfer prints of the sole were created on different types of surfaces i.e. a piece of white A4 paper, a piece of newspaper, rubber mat, a dark brown and black stripes carpet, and a red coloured carpet.

iii. Photography

For each print, a piece of ruler was placed next to the print for photographic purposes. This ruler created a dimension for the shoe and was used for measurement purposes. Each print was photographed (in close-up range and at the same range of length, with fired flash) using Canon EOS 40D digital Single Lens Reflect (SLR) camera with a Canon macro lens EF 100 mm USM. All of the images were saved in raw file format (raw).