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Study on the Variability of Printed Documents produced by LaserJet Printers (HP LaserJet P3005 Printers)

Dissertation submitted in partial fulfillment of the Degree of Bachelor of Science in Forensic Science

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ABSTRACT

This study looks at the variability of prints produced by LaserJet printers. Five HP LaserJet P3005 printers were used to print out a letter consisting of a mixed of letters and numbers at different fonts. Seven duplicates were printed from each printer and compared using a stereomicroscope. Printed samples were also obtained from two selected printers in time interval of a week over a period of about a month.

Results based on microscopic examination by stereomicroscope on the printed documents from some printers of same brand and model had shown specific characterizations. Some specific individual patterns are shared by a subgroup of printers that used in our study. Though, it is difficult to link such printed material to an individual printer, this study helps to include or exclude the possible source of the printer from same brand and model. Microscopic examination on the printed documents printed over a period of four weeks revealed the drastic changes between first week and third or fourth week in terms of the thickness of the alphabets appears to be caused by insufficient toner. Hence, it enables to determine the order of printed materials in terms of the time interval of a few weeks. This study agrees with previous reported observation stating that individual characterization of the printed documents can be used to link a document to at least a group of possible printers.

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INTRODUCTION

A document can be defined as an item that contain writings, symbols, marks whether visible or invisible and conveys a meaning for someone (Moorty *et al.*, 2010). A questioned document need not be a piece of paper; it can be any object (Houck and Siegel, 2010). To be a document, it must contain linguistics or numerical markings that are put there by handwriting, typewriting, copying, computer printing, or other means (Houck *et al.*, 2010). Document examination is defined as a discipline in which a document is examined and analyzed in order to obtain information that can be used to serve the justice system based on scientific explanations (Morris, 2000). Document examiners are often called upon by the court of law to compare typewritten or computer generated documents, analyze inks and papers, determine the age of a document, uncover credit card and forgeries and currency fraud, and reconstruct charred or obliterated writing (Houck *et al.*, 2010). The field of questioned document examination is one of the "pattern evidence" areas of forensic science in which examiners must reach conclusions based solely on their expertise, where no instrumental backup is available to confirm a conclusion (Houck *et al.*, 2010).

Printed documents are subjected to different considerations than from handwritten ones (Houck *et al.*, 2010). Except under unusual circumstances, mass production of machines such as typewriters, printers, and copiers prevents individualization of a document to a particular machine. The only exception to this rule is in the case in which there is a defect in the printing or copying mechanism that results in the repeated appearance of an unusual or unique characteristics, or preferably several such characteristics (Houck *et al.*, 2010).

Printed material is a direct accessory to many criminal and terrorist acts (Khanna *et al.*, 2006) with examples including forgery or alteration of documents used for purposes of identity, security, or recording transactions (Khanna *et al.*, 2006). In addition, printed material may be used in the course of conducting illicit or terrorist activities (Khanna *et al.*, 2006). Examples of these documents include instruction manuals, team rosters, meeting notes, and correspondence. In both cases, the ability to identify the device or type of device used to print the material in question would provide a valuable aid for law enforcement and intelligence agencies (Khanna *et al.*, 2006). In recent years, there has been a gradual move from manual and electronic typewriters to electronic word processors for the production of typewritten documents (Arboiune and Day, 1993).

The 'Computer Age' has brought with it a new challenge for the questioned document examiner (Blanco, 1992). Modern computers and their companion printing devices such as dot-matrix, daisy wheel, ink-jet and laser printers, are capable of printing a wide variety of standard, as well as new and unique characters, often at incredibly high speeds. However all these high-tech jargon and sophisticated equipments need not intimidate the questioned document examiner (Blanco, 1992). Proven and standardized methods of examination are still applicable in identifying documents printed by these equipments (Blanco, 1992). The popularity of word processing has brought about an associated increase in computer printouts on various types of printers, including laser printers (Arboiune *et al.*, 1993).

As a result, document examiners are likely to encounter more laser-printed documents in their casework, making it necessary to have a means by which they can identify a particular

printer as the one used for the production of a questioned document (Arbouine *et al.*, 1993). The widespread use of laser printers has made it necessary for document examiners to find a method linking a questioned document to an individual printer (Arbouine *et al.*, 1993). Additionally, there are a number of applications in which it is desirable to be able to identify the technology, manufacturer, model, or even specific unit that was used to print a given document (Khanna *et al.*, 2006).

Forensic characterization of a printer involves finding intrinsic features in the printed document that are characteristic of that particular printer, model, or manufacturer's products. This is referred to as the intrinsic signature. The intrinsic signature requires an understanding and modeling of the printer mechanism, and the development of analysis tools for the detection of the signature in a printed page with arbitrary content (Ali *et al.*, 2003; Mikkilineni *et al.*, 2004a, b, 2005a, b; Arslan *et al.*, 2005).

LITERATURE REVIEW

1.0 Document Examination

Within the wide field of forensic science, the scientific examination of documents has one purpose: to provide information about the history of a document for the benefit of a court of law or, before that, to an investigating police officer or other agent seeking evidence that might be present in the document (Scientific Examination of Documents: Methods and Techniques, SEDMT, 2006). Comparison is important in many fields of crime investigation (SEDMT, 2006). Traces of blood, glass, paint, and fibers are left at scenes of crime or are transferred from the scene to the culprit. Similarly, marks made by tools, fingers, or shoes of the attacker can be found at a scene. It is of importance to show whether the traces or marks match their possible origin and, if they do, how likely it is that they could have come from a different source. Similarly, identification and comparison are essential in the forensic examination of documents (SEDMT, 2006).

The traditional approach in the discipline of Forensic Document Examination is best expressed as follows: "When any two items possess a combination of independent discriminating elements (characteristics) that are similar and/or correspond in their relationships to one another, of such number and significance as to preclude the possibility of their occurrence by pure coincidence, and there are no inexplicable disparities, it may be concluded that they are the same in nature or are related to a common source (the principle of identification)" (Conway, 1959).

2.0 Printing Devices

Like pens, inks, and typewriters, photocopiers and printers have evolved over the decades. In fact, many models now incorporate the two, along with faxing capabilities, in a single multi-use machine (SEDMT, 2006). Some of the earliest copier models used a liquid toner. Recently, dry toner became the standard (SEDMT, 2006). Another change was a move from analog to digital image processing. In the past two decades, advances in inkjet technology were observed such that it has taken a prominent position alongside electrostatic imaging (SEDMT, 2006). Dot matrix technology has, to some extent, fallen by the way, though still an important device for imprinting on multipart NCR (no carbon required) forms and therefore can be encountered from time to time in questioned document cases. A study of the document will generally reveal the copying or printing method used (SEDMT, 2006), and therefore it is the aim of this section to review techniques and technologies in printing of documents.

2.1 Word-processed Documents

In the modern office environment, computer based word processer systems have almost totally eclipsed typewriters as the means of document production (Jackson and Jackson, 2008). In essence, keyboard operators use word processer programs in order to compose documents, which are then usually stored electronically on computer file. These files may be printed out as and when required, using any of the several types of computer printers available on the market. Currently, there are mainly three types of computer printers that are currently in common use (Jackson et *al.*, 2008), like dot matrix, bubble jet and laser printers which will be described in the following sections.

While it is possible to class a printed document to its 'type' of printer used, it is difficult to link a document with a specific computer printer beyond the level of its class characteristics (Jackson *et al.*, 2008). For example, in the case of inkjet printer, the printed text with blurred outline, which are characteristics of documents produced by this type of printers (Jackson *et al.*, 2008). However, the identification beyond this level is much more challenging. In contrast, in laser printers, it may possible to link a particular document with a suspect printer, or show that two or more documents have been printed out on the same machine, if there are faults present on the drum that are transferred to the printed page (Jackson *et al.*, 2008) . In such cases, the appearance of more than one mark per page is usual and is due to the fact that the drum characteristics is generally less than the length of an A4 piece of paper (Jackson *et al.*, 2008) .

2.2 Types of Computer Printers

This section reviews the three main types of printers commonly used with computer:

a) **Dot matrix printers**: This is the oldest type of computer aided printer. It corporate a printer head that contains and controls a series of electromagnetically operated pins. Specific configurations of these pins correspond to individual printed characters. When the configured pins strike the paper through an inked fabric ribbon, they transferred a series of ink dots onto the paper to produce the desired character in printed form (Jackson *et al.*, 2008).

Figure 1.1 shows a type of dot matrix printer (Source: Yahoo)

b) **Ink jet printers:** In inkjet printers, ink is forced through a nozzle to form the printed characters. The exact mechanism by which the ink is delivered depends on the type of inkjet printer used. Briefly, in continuous stream printers, ink is delivered in a continuous stream and formed droplets that are subsequently charged. Those charged droplets needed to form the printed character are deflected towards the paper, while

the remainder is ultimately returned to the ink reservoir. In contrast, 'drop on demand' printers have a grid of minute nozzle through which only those ink droplets needed to make up the printed character are forced (Jackson *et al.*, 2008) .

Figure 1.2 shows a type of inkjet printer (Source: Wikipedia)

c) **Laser printers**: Laser printers are those use Xerography, do not use ink to make characters on the paper (Houck *et al*, 2010). Instead, the characters are made using a toner made from finely divided carbon powder and binders and a laser (Houck *et al.*, 2010). Laser printers work on similar principles to those on which standard photocopiers are based. The main difference is that the image produced by a laser printer is created as 'dots' on the light-sensitive surface of the drum by means of a laser beam rather than as an optically produced copy of an original document. Laser printers use dry toner powder which is fused onto plain paper by either heat or pressure or a combination of both. The dot size and spacing are small (typically at

about 0.08 mm), and the dots overlap to give characters of a continuous appearance (Allen, 1987).

Figure 1.3 shows a typical laser printer (Source: Wikipedia)

If the cartridge that contains the toner starts to run out, then the print quality may become irregular, but this will change with time and may not be of much help (Houck *et al.*, 2010). In some situations, however, extraneous marks or blotches of toner may show up repeatedly in the same location until the machine is cleaned or repaired (Houck *et al.*, 2010). If the questioned document and the copies show specific markings in same location on the copy, they may provide individual information about the source of the questioned document (Houck *et al.*, 2010).

According to Houck *et al.* (2010), it would not be necessary for the examiner to have the printer or copier. Instead, whoever investigates the incident should make sure that an adequate number of examples are taken to show the degree of consistency of the extraneous markings. If there are no reproducible extraneous markings on the paper, and the source of copy is not known, it may still be possible to determine the maker of the copier or printer by chemical analysis and comparison of the toners with known samples (Houck *et al.*, 2010). This evidence is not individual, however; it is normally not possible to determine with certainty that a particular machine was the source of a questioned document.

3.0 Electrophotographic (Laser) Printer Architecture

Electro photography (EP), also referred to as xerography, is the underlying marking technology for laser printers and office copiers (Chiang *et al.*, 2009). There are six steps in a typical EP process: charging, exposure, developing, transferring, fusing, and cleaning. Typically, an organic photoconductive (OPC) drum, also called a photoreceptor, rotating at a constant angular velocity, is electrostatically charged through a charger roller (Chiang *et al.*, 2009). A latent image is then exposed onto the OPC drum by scanning a pulsed laser beam with a rapidly spinning polygon mirror and discharging specific locations on the OPC surface. A toner image is developed by electrostatically adhering toner particles to these areas of the OPC surface that were discharged by the laser beam. The developed image is then transferred electrostatically onto the output media (paper) through a charged transfer roller. The toner image on the paper is then fused to the paper through heat and pressure by the fuser (Chiang *et al.*, 2009). To prepare to print the next page, the surface of the OPC drum is cleaned to

remove any residual toner by a cleaning blade that scrapes across the OPC surface (Chiang *et al.*, 2009).

3.1 The Laser Printing Process

According to Arboiune *et al.* (1993), laser printers contain a photosensitive drum which is given a uniformly positive charge by corona discharge units. A laser, after receiving information from a computer or word processor, is scanned across the drum, dissipating the charge in specific areas and leaving the image of the document on the drum surface with a positive charge. The drum is sprinkled with negatively-charged toner which clings to the positively-charged areas on the photosensitive surface. A sheet of paper is passed over the rotating drum and given a positive charge, to allow the transfer of the toner from the drum to the paper. The toner is fused to the paper by heat or pressure, and the drum surface is then wiped clean to remove any remaining toner, so that the process can begin again. In order to keep the drum size small, a whole page is often composed on the drum surface in stages and so more than one complete rotation of the drum is needed to print a single page of a document. Consequently, a fault on the drum will be transferred to the paper on each rotation of the drum during the printing process and will therefore occur several times on the same piece of paper. It is therefore possible to determine whether questioned laser-printed documents were printed on the same machine and to link such documents to an individual printer (Arbouine *et al.*, 1993).

3.2 Laser Printer Signatures

The inherent artifacts generated by EP printers due to their physical components such as gear mechanism, polygon mirror wobble, and optical photoconductor (OPC) angular velocity can be used as an intrinsic signature of the device (Chiang *et al.*, 2009). Laser printers can be characterized using intrinsic signatures such as banding (Ali *et al.*, 2003). Banding is an artifact caused by fluctuations of the OPC angular velocity and errors in the gear transmission mechanism (Chiang *et al.*, 2009). It appears as nonuniform light and dark lines perpendicular to the process direction. This is the direction in which the paper moves through the printer.

Different printers have different sets of banding frequencies, depending on brand and model (Chiang *et al.*, 2009). Banding-based identification is based on frequency-domain analysis of a one-dimensional (1-D) projected signal of large midtone regions of the document, typically occurring in printed images (Chiang *et al.*, 2009). Fourier analysis of the signal yields the banding frequencies. Here, the 193 cycles/inch peak corresponds to the tooth-to-tooth error of the large gear, and the 24 cycles/inch peak corresponds to the eccentricity error associated with the small gear. With tooth-to tooth error, each cycle of the banding noise corresponds to the angular separation between succeeding gear teeth. With eccentricity error, each cycle of the banding noise corresponds to a complete revolution of the gear (Chiang *et al.*, 2009). Since one revolution of the small gear corresponds to the meshing with large number of teeth of the large gear, the noise associated with the large gear will be at a much higher frequency than the noise associated with the small gear (Chiang *et al.*, 2009). This conclusion is based on a precision measurement of the individual gear components of an actual printer unit, as

well as an analysis of the manner in which the fluctuations propagate through the gear train to the OPC drum (Chiang *et al.*, 2009).

In a text-only document, the absence of large midtone areas makes it difficult to capture suitable signals for banding analysis according to the method just described (Chiang *et al.*, 2009). In this case, texture features estimated from individual text characters can be used to capture the intrinsic signature. Texture is a consequence of the fluctuations in the developed toner due to electromechanical imperfections. A set of texture features is based on the gray level co-occurrence matrix (GLCM) (Mikkilineni *et al.*, 2005; Ali *et al.*, 2004). These features are estimated from printed text regions and are classified using pattern recognition techniques such as support vector machines (SVMs), principal component analysis (PCA), and Gaussian mixture models (GMMs). Other techniques that can be used to intrinsically characterize EP printers include measures of image sharpness, toner fusing characteristics, dot gain, and the asymmetry of toner distribution (Oliver *et al.*, 2002). In addition, an optical effect due to the toner particles lying on top of the paper is characteristic of EP printers (Wolin, 2002). A surface-profiling apparatus can display how printed areas extend above the surface of the paper.

3.3 General Extrinsic Signatures for Printing

Printers are complex electromechanical devices. Imperfections in the printer mechanism, such as imperfect gear meshing or motor speed fluctuations, are always present (Chiang *et al.*, 2009). These imperfections directly affect the printed output. For example, as discussed earlier, fluctuations in the optical photoconductor drum angular velocity will cause the spacing between scan lines to vary, which creates banding in the printed page. The effects on the printed output can be directly correlated with the mechanical properties of the printer. It is because of this direct correlation that these features can be used as an intrinsic signature of the printer (Chiang *et al.*, 2009). The intrinsic signature can be used to determine the device that created a document, and in some circumstances it also provides a level of tamper-proofing for the document. However, in many security applications there is a need to embed additional content in the printed form of the document to provide a margin of safety that cannot be achieved with intrinsic signatures alone (Chiang *et al.*, 2009). Examples include a secure hash of the document, the serial number of the printer, or the date and time of printing. Various methods exist for embedding additional content in a document; they fall into two basic categories. The first includes methods that embed security information in the document before it is sent to the printer. These methods are typically designed such that the embedded security features are able to survive the printing process (Chiang *et al.*, 2009). The second category includes those methods that embed security features at the printer-mechanism level. Performing the embedding in the printer allows a broader domain for marking the print and makes attacking the security features more difficult.

3.4 Printed and Photocopied Document Examination

Any examination of faxed, photocopied, or computer-generated materials should include a general assessment of the printing technology employed (SEDMT, 2006). As many printing methods exhibit visually distinctive characteristics, identification can often be achieved through microscopy with the aid of various light sources (SEDMT, 2006). The identification of the printing technology used can often shed light on the plausibility of testimony given as well as offer the potential to expose text insertion or page substitution (SEDMT, 2006). In the event that a single printing method is determined, it may be possible to further classify the technology and distinguish differences in printer settings, or even differentiate printers, through the use of more sophisticated examination techniques (SEDMT, 2006). Toner particle characteristics and dispersion patterns on documents produced with laser printers or photocopiers can be examined and compared using Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), confocal microscopy, or energy dispersive x-ray (EDX) (SEDMT, 2006). Some marking media, such as bubble jet/inkjet ink and sublimation dyes, can be distinguished from one another through the use of infrared or ultraviolet examination (SEDMT, 2006).

With regards to the electrostatic photocopying process, a further sub classification can be made between those machines employing analog technology and the newer digital systems (SEDMT, 2006). While it may seem, at first glance, to be a simple matter to identify the pixilation created by digital copiers and contrast it with the non-digitized images created by analog machines, considerable care must be taken to ensure that any pixilation observed is not simply a reproduction of characteristics found in the original or an intermediate generation

copy (SEDMT, 2006). With modern laser printer output resolutions in the 1200- to 2400-dpi range, the forensic document examiner must be cautious when identifying a document as an analog photocopy (SEDMT, 2006). At these resolutions the pixel width is so small that toner particle size, toner clumping, and paper fibers may pose significant interference problems in assessing digitization, even at high magnification (SEDMT, 2006). The ability to determine whether more than one machine has been used to produce text within a multi-page document, or even between one area and another on the same sheet of paper, is sometimes of critical importance (SEDMT, 2006). While gross differences may be evident upon microscopic analysis, other differences can only be detected using more sophisticated analytical tools. Leading-edge research is being conducted to measure print quality with the use of specialized machine vision systems. Using these tools, the document examiner can evaluate such parameters as dot position, edge raggedness, overspray, satellites, and text quality, to name a few (SEDMT, 2006).

The defects produced by fax machines, copiers, and computer printers can have value in identifying material generated on more than one machine and therefore can be used to identify substitution of pages or even interlineations on a single sheet (SEDMT, 2006). For example, a printing void may appear on all but one page of a computer-generated last will and testament. This discrepancy, together with other differences (such as in paper, staple holes, and writing indentations), can demonstrate that there has been page substitution. The true value of these examinations lies in their use as comparative techniques, that is, the comparison of one portion of the document with another to establish whether or not there is consistency throughout. Similarly, the findings may be compared to the output of machines put forth as

having been used to create the document, allowing them to be included or excluded as the possible source (SEDMT, 2006).

Many of the examinations involve comparisons of genuine documents with suspected counterfeits, so there is a need to compare methods and quality of printing as well as the inks or toners used (SEDMT, 2006). It is sometimes necessary to determine whether a number of printed documents all originated from the same source. It may be necessary to show, if a document differs from the genuine product, how it has been printed and from what original it has been copied (SEDMT, 2006). In other cases, the plate or some other part of the printing press can leave evidence that it was the source of the counterfeit. Photocopies present other problems; the original material copied may need to be established, or the maker of copier used, or the individual machine may require identification (SEDMT, 2006).

To allow proper evidence to be deduced from the document in question, some knowledge of the printing process is necessary (SEDMT, 2006). Certain questions can be answered only by a printing technologist, but in many investigations the document itself and its scientific examination will provide adequate evidence when the observations are interpreted properly (SEDMT, 2006). The main methods of printing, and the ways in which the products can be recognized, will be briefly described in this chapter. Printing inks and their examination are also considered (SEDMT, 2006).

According to SEDMT (2006), laser printing and other matrix methods also produce jagged edges, especially on diagonals. The dots making up the image are arranged in a grid pattern, so only vertical and horizontal lines appear continuous, whereas diagonals are stepped. The

appearance of toner or ink varies between the different matrix inks. Those using liquid inks appear much like lithographic printing, but laser printing depends on the fusing by heat, or pressure, or both, of small particles of solid toner (SEDMT, 2006). This results in a solid black shiny conglomeration together with small, black, adventitious dots where there is no image. Documents produced on plain paper copiers have a similar appearance to those produced by laser printers. The same methods of indirect electrostatic image production apply to both, and only the serrated diagonals of laser printing, detected by close examination, can distinguish between them. Even this does not provide certain discrimination, because with improved methods of laser printing, using a finer matrix, the serrations are less pronounced (SEDMT, 2006).

The printed images of plain paper copiers and laser-printed documents are not produced by liquid inks drying on the paper but by resinous particles fusing or compressed on the surface (SEDMT, 2006). The effect is therefore very different. Most plain paper copiers use dry toners, which are, when forming an image on a photocopy, built up on the surface rather than partly absorbed in it (SEDMT, 2006). Unlike conventional printing inks, whose appearance under magnification will not vary greatly, especially when one type of printing is considered, different toners can be distinguished by microscopic means. Ordinary low-power magnification can detect differences in the morphology of the fused or compressed toner, but a greater distinction can be made by using the scanning electron microscope (SEDMT, 2006). Using magnifications of around 1,000 or 2,000 × the structure of the toner surface can be examined and distinction can be made between one toner and another (SEDMT, 2006).

Further tests can be made to ascertain the chemical composition o the toner. The scanning electron microscope can again be used, this time to determine the elemental composition. Pyrolysis mass spectroscopy and infrared spectroscopy are used to identify or compare the organic resins that are an integral part of all dry toners. Iron-containing toners can be distinguished by their susceptibility to being magnetized (SEDMT, 2006). Apart from the latter, which is nondestructive, these tests require a very small quantity of material (less than a square millimeter) and they can show whether or not two toners are similar, or they can identify the manufacturer (SEDMT, 2006). It is not possible by these means to identify a particular machine, merely a type of toner, and therefore the probable make o machine (SEDMT, 2006). Although it is not impossible for a toner to be used in a machine for which it was not designed, this does not often happen; most toners are packed in special containers made especially for a particular model of photocopier (SEDMT, 2006).

3.4.1 Machine Characteristics

Apart from the analysis of toner, which gives an indication of the type of machine used to produce a copy, extraneous marks on a copy can provide additional information (SEDMT, 2006). These falls into two classes: those that, like the composition of the toner, can identify the make and model of a photocopier and those that will identify the individual machine used to make the copy or that was instrumental in its preparation (SEDMT, 2006). A photocopier depends on mechanical means for handling the paper. These can leave characteristic marks on the copies and therefore give an indication of the model used (SEDMT, 2006). They range from indentations caused by grippers or rollers to marks made by toners in certain parts of the

copy. If the page being copied does not fill the area allowed for it, parts of the cover can be copied; this may give a clear indication of the type of machine used (SEDMT, 2006). Photocopiers do not produce copies of exactly the same size as their originals. There is usually a slight enlargement of around 1% in the copy, which is not necessarily the same in each dimension (SEDMT, 2006). Many copies are capable of much greater magnification as well as reduction. These properties can also show the type of machine used (SEDMT, 2006).

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3.4.2 Identification of the Photocopy with the Copier

Apart from those marks that are characteristic of model, other marks appear on a copy caused by dirt, damage, or malfunction of the machine (SEDMT, 2006). These can arise from scratches, dust, or other material on the platen, the glass plate that supports the document being copied; on the lid that covers it; or on the drum on which the image is first formed (SEDMT, 2006). Other problems can also occur, such as defects in the corona wire that charges the drum or in the mechanism that puts toner onto it (SEDMT, 2006).

Marks on the platen, lid, or drum can be permanent or temporary (SEDMT, 2006). Even those described as permanent can be removed if the part itself is changed. Those on the platen will occur each time a document is copied those on the lid only when it is exposed by an incomplete covering of the platen, and those on the drum will occur regularly but not necessarily at the same frequency as copies are produced. This means that such marks on the drum may show at a different place on successive copies or not at all on some, depending on the diameter of the drum (SEDMT, 2006). Defects in charging, application of toner, and

transport of paper will show as extra lines down the paper or in poor copying in places on the page (SEDMT, 2006). They are normally temporary because the faults that cause them are usually soon rectified (SEDMT, 2006).

The most significant marks are those that are randomly formed by dust or damage (SEDMT, 2006). These give specks or dots anywhere on the copy and sometimes form groups rather like constellations of stars that are easily recognized on all copies on which they occur (SEDMT, 2006). These "trash marks," as they are sometimes described, may be produced for a long time, or they may b completely or partly removed or added to. Therefore, although all such marks on two photocopies may not match, a reasonable number that can be easily superimposed, by the use of either photographic transparencies or a comparison projector, is clear proof that the same machine has been used in the production of both (SEDMT, 2006). Their random nature indicates that chance match is extremely unlikely (SEDMT, 2006). In some cases, the period during which a copy was made can be established because there is a gradual change in the pattern of the marks (SEDMT, 2006).

It is also possible to establish that a copy has been recopied on the same machine if the constellation occurs twice on a document. The presence of characteristic marks on a photocopy does not indicate that it must itself have been made on the particular machine (SEDMT, 2006). It may be a copy of another that was made on that machine, the marks having been reproduced along with the rest of the information. Some photocopies exhibit marks from more than one machine, indicating that copying of copy has taken place, but with clean equipment there may be little to show this (SEDMT, 2006). Testing of the paper and

toner can then assist in establishing if the copies have different origins. Some laser color copiers add latent images, which are different for each machine; onto the copies they produce (SEDMT, 2006). This enables the manufacturer to identify the individual machine used to make the copy (SEDMT, 2006).

4.0 Photography

There are three main functions of photography in document examination to make a permanent record of the document before it is damaged in the course of certain examinations, to detect certain features that are not visible and for which other methods are unavailable or less convenient, and to prepare material from which demonstration charts for use in courts are prepared (SEDMT, 2006). A properly prepared photograph of a document is capable of displaying most of the information visible on the original and can therefore be used as a substitute for it in a court or in preliminary investigation (SEDMT, 2006). The preparation of a high-quality photograph made for a record in such cases requires considerable expertise. Without proper care, there may be lack of sharpness due to poor focusing, or too much or too little contrast caused by the use of the wrong exposure, developers, or materials. Inadequate or uneven lighting also produces poor results (SEDMT, 2006).

A photograph taken as a record, although of good quality, will not always be an adequate substitute for the original document for scientific examination. The recording of the evidence was done by mean of photography using digital camera (Moorty *et al.*, 2010). Without the right lighting conditions, it may not be possible to detect evidence of tracing, and without

adequate magnification the method of the construction of the handwriting may not be visible (SEDMT, 2006). In many cases, however, it is possible to find on a photograph adequate material on which to base a firm conclusion if the document is no longer available or is not in a suitable condition for direct examination Magnification is an important feature of document examination. Some enlargement can be produced by the use of photography and video methods, and also by a magnifying glass, but the optical microscope is the most frequently used tool of the examiner (SEDMT, 2006). There are many arrangement of lenses and lighting systems that are described as microscopes, but the stereo microscope, which gives a magnification of around 10–50x with a relatively wide focal range, is the most suitable for document examination (SEDMT, 2006). Lighting can be provided from any direction, but for most examinations illumination from above is most convenient (SEDMT, 2006). Most commercially available stereo microscopes provide a range of magnifications, using either a series of different lenses on a turret or a zoom lens, which gives a continuously variable range (SEDMT, 2006).