Crossing Ink Lines - Forensic Evolution and Its Objectives - Comprehensive Review

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Abstract- Drawing paintings to granting global fund "ink" plays a vital role. Ink produced on the writing surface via pen, stamp pads/ink pad, type writer and printing media is unified topic for all. this literature review mainly focused on ink, properties of ink, methods and methodologies followed with facts for determining crossing ink lines sequence. Main scope of this study to give the insight towards forensic inventions evaluated over the period and also tribute to those pioneer authors for their research contribution. For this purpose, selected 30 research papers published related to ink analysis have been studied, advantages and confines were explained.

Indexed Terms- Destruction Technique, Ink Penetration, Polarity, Resolution

I. INTRODUCTION

In ancient technology writing is considered as beautiful art. Even though digitalization conquers the world, paper and pen has its evergreen role till today. Document examination not only dealt with hand writing or signature, but in wide sense "writing surface and ink" with which it made off. One of the sensational issues caught the interest of researchers is the determination of the sequence of crossing ink lines, i.e., determination of the order in which two ink contributions that intersect each other were made in a questioned document. Dean John. H. Wigmore wrote in his book titled questioned documents as "Each age has its own crimes, with corresponding protective measures- all alike the product of the age's conditions. In each age, crime takes advantage of conditions, then society awakes and gradually over-comes crime by discovering new expedients". In present scenario, as he wrote as technology improved frauds are happening with utilizing contemporary methods for which better advanced scientific trends to be identified.

Traditionally examination of ink has been done only for quality controlling purpose. Over the timeline, examiners and chemists observed that, ink has unique features with which document can be authenticated and its integrity can be maintained under the purview of judiciary system. In this study, about 30 research papers have been selected from different database and challenges are studied. Main scope of this literature review is to provide inclusive scientific trends and its input towards examination of "ink" sequence instead of mere subjective illustration.

Ink: It is composed of a pigment or dye dissolved or dispersed in a liquid called vehicle and used for writing and printing. Ink was called 'Mas' or 'Masi' in ancient India. they primarily used palm leaf or "TaalPatra" as a base to document information. the most ordinary form of ink was prepared by mixing powdered charcoal with gum and sticky substance dissolved in water would finally determine the colour of the ink.

The ink composition and physical features of various modes such as pen, stamp-pad/ink pad, type writers, and printers are different. It is necessary to look upon the parameters which affecting the ink sequence so as to choose appropriate scientific method.

Penink: Oil/Glycol, liquid, and alcohol-base dinks are the three basic forms of ink. The water-base dare polar and comprises of a mixture of dyes. alcohol-based inks dissolve in alcohol. The glycol-based inks are dissolve in oil. The oil-based inks are much thicker than the other inks. Typically, ball point pen ink comes under Oil/Glycol category. fountain pen, gel pen, felt tip pen ink, Rollerball Marker pen ink comes under water-based ink.

Printer ink: There are four interdependent components in the printing system such as press, plate, paper and printing ink. Ingredients used in the

manufacture of printing ink fall into three main classifications i.e., fluid/vehicle, solid ingredients or pigments and supplementary additives, driers and other compounds.

Fluid ingredients/vehicle: the vehicle may be broadly enumerated as Non-drying oil, drying oil, solvent resin, glycol, resin oil, resin wax, water soluble and photo reactive.

Pigments: these are the solid colouring matter in inks may be black, white, inorganic colour, metallic powder, organic colour and flushed colour.

Dyes are used because of their optical properties and primarily used as "toners".

Additives: to impart unique characteristics to ink additives such as surface-active agents, driers, starches, wax, antioxidants, gums and lubricants are utilized.

Type writer ribbon ink:
The strong solutions of an iline dye stuffs in spirit or water, with an addition of glycerine is used in earlier preparation. Modern type writers contain ground pigments like lamp black, coalter dye lakes, Prussian blue, malachite green, oil soluble dyes and others.

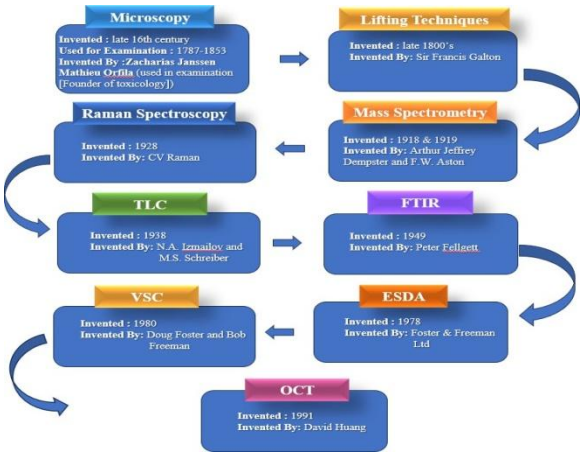
Stamp pad ink:
Inks are heavily loaded with humectants such as glycerol or glycol, which prevents the pad from drying up. Some of the quick drying pad inks contain solvents such as acetone, methyl alcohol or ethyl acetate, instead of aqueous solutions.

Crayon ink:
The active ingredient is mixture of wax usually paraffinorcarnauba coloured by the addition of oil -soluble dye stuffs or pigments produced by depositing a dye on a white mineral base known as lakes.

Importance of forensic examination of ink: It is normally performed to determine the ink source/ common origin, study of basic properties of ink, ageing of ink and most significantly to find out order in which two or more ink lines are produced.

II. ERAOFMODERNSCIENTIFIC APPROACH

Prior to 1950 ink examination was limited to colour identification observed under light wavelength ranging from ultra violet to infrared. After 1950 is era of revolution in which experts are decided for in-depth analysis of ink using scientific tools based on its availability.



III. INSTRUMENTS AND ITS PRINCIPLES-CASE STUDIES ON SEQUENCE DETERMINATION-A ESSENCE

Plentiful research has been proposed and performed on "ink analysis" and "Sequence of crossing of ink lines". Analysis includes both destructive techniques (the sample may get destroyed or deformed during the process of either examination or pre-examination i.e., sample preparation) such as thin layer Chromatography, lifting methods and non-destructive techniques (the sample remains unaffected/int act which maybe used /preserved for further investigation of cases) tools such as Microscopy test of ink, ESDA, Chemical analysis with IR, fluorescence technique, Laser Scanning Confocal Microscopy (LSCM), Chemical analysis with Raman spectroscopy, Atomic Force Microscopy (AFM), 3D Laser profilometry, VSC with Hyper spectral imaging, confocal microscope and a white-light scanning interferometer, Attenuated Total Reflectance–Fourier Transform Infrared (ATR-FTIR) imaging, OCT (Optical coherence Tomography),Mass spectrophotometry.

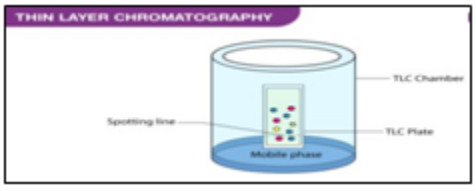
Thin Layer Chromatography: TLC is a rapid technique for the separation of the organic components of ink and enables an easy comparison of the visual ingredients (dyes) in the various ink formulations.

Review Study and observations:
Omprakash jasuja. et.al. made an experiment to identify stamp pad inks of similar colour with different dye composition. Stamp pad inks of four commonly used Indian brands namely Ashoka.

B.C.R. Camel and Korea have been analysed by thin-layer chromatography. Author observed that, dye constituents of all the four colours could not be separated with one solvent system, rather different solvent system is required.

Ranjit Singh verma.et.al proposed an experiment to study the colour constituents used in preparing various shades of fibre-tippeninks. Twelve sign-pen inks of three brands, Luxor-camlin, Ecko, and Fleet pearl, available in the local market have been studied. Author observed that, separation and differentiation of colour constituents present in various fibre-tip pen inks is possible by TLC.

G. R. Nakamura.et. al conducted experiment to study the dye components present in the different ball point pens using TLC method followed by spot test. Authors Used "Punch Method" with hypodermic syringe for removal of small portion of ink and solvent mixture (1-butanol: 50, ethanol: 10, water: 15) for analysis. They observed most of the ball point pens having similar dye components.



Principle: Thin-layer chromatography (TLC) depends on the separation principle. The separation relies on the relative affinity of compounds towards both the phases. The compounds in the mobile phase move over the surface of the stationary phase.
Lifting Technique: In this technique authors mainly focused Kromekote paper and glossy paper for lifting purpose.

Kromekote paper: Krome Kote, a product of the Champion Paper Company, is a 'cast coat' type paper. A 'cast coat' paper is defined in a Technical Association of the Pulp and Paper Industry publicationofOctober1971, number CA1522 as:"A paper or board, the coating of which is allowed to harden or set while in contact with a finished casting surface. Cast coat papers have in general a high gloss." The manufacturer states that the composition of the coating is 86% inorganic pigment (calcium carbonate and kaolin) suspended in an organic binder consisting of case in and styrene 1:but a diene latex. The organic binder constitutes approximately 13% of the coating. Exceptional printability and performance ensure realistic, highly detailed images and vibrant, saturated color. Its resilient surface allows for clean, crack-resistant folding and scoring. Paper commonly referred to as C1S (coated one side) or C2S (coated two sides). usually, the coated side is glossy.

Glossy Paper
Coated paper also known as (enamel paper, gloss paper, and thin paper) is has been coated by a mixture of materials or a polymer to impart certain qualities to the paper, including weight, surface gloss, smoothness, or reduced ink absorbency.

Review study and Observations
Gupta et .al recommended the use of pyridine solution and photographic glossy paper for transferring of inks. The author also commented that this technique can be used with crossings made with ballpoint pen inks but greatly depends on the pressure employed during the writing, since varying results were obtained with samples prepared with different writing pressures.

Igoe and Reynolds suggested a modified approach based on the Kromekote lifting technique instead of using glossy paper to study intersecting of ball point pen inks. This method consists in placing the glossy side of a Kromekote paper over the crossing area in a document and applying pressure and heat on both sides with a tacking iron or just pressing without heating, for a certain period of time. The two papers are then separated and the reverse image of the

crossing that is transferred to the KromeKote paper is examined. It is expected that the ink applied last would be favoured during the transferring process and would be visible in greater concentration in the KromeKote paper. The authors also reported that this methodology was limited to ballpoint pen inks and can give unreliable results with pencils and fluid inks. They also concluded process was affected by physical parameters such as pressure, temperature and abrasion.

Leung.et.al used the Kromekote technique for intersecting ballpoint pen strokes using rubbing pressure and optimal pressure method with "railway effect theory". author observed that the method is valid provided that the intersecting strokes are similar in width. It also affected by other factors such as property of ink and amount of ink deposited, passage of time causes the ink to become dry and be absorbed into the paper, the surface of the paper, the speed of the writing instrument. Therefore, they advised to use microscopy and VSC techniques before applying "Kromekote Paper "technique.

Jacques Mathyer and Roman Pfister surveyed the methods followed by previous authors. He used both "Kromekote Paper method "and" Scanning Electron Microscope" for study. Authors suggested both the methods are complex and they have their own limitations.

Microscopy: It is an instrument which deals with too small sample that they cannot be seen distinctly with the naked eye. There are 3 main categories: Optical Microscope, Electron microscope, light microscopy involves use of optical lenses and light radiations.1000AD – The first vision aid was invented (inventor unknown) called a reading stone. It was a glass sphere that magnified when laid on top of reading materials and 1284 - Italian, Salvino D'Armate is credited with inventing the first wearable eye glasses.

Principle: Microscopes provide the observer with enhanced resolution (ability to observe two nearby objects as distinct objects), contrast (ability to detect different regions of the specimen on the basis of intensity or color) and magnification (ability to make small objects visible).

Review study and observations:
Linton Go down explained crossing intersection of ball pen, type writer, pencil and fluid ink pen in his paper "sequence of writing". The author observed that, stereo micro scope under 50xis suitable for the experiment. He also explained about the constraints which affects the analysis in the paper.

Julio H. Bradley proposed a method to determine the sequence of crossings made with graphite, by copying and with color pencils using a stereomicroscope with 30x magnification and side illumination at a 30-40º angle. In this case, the physical features examined were the continuity of the grooves, striae, brightness, particle deposition and color intensity. But it failed in real case examination.
Strach examined crossings made with ball point pen inks using an optical microscope with 20x magnification. The physical features are evaluated were the edges of the line at the crossing region.

Radley argued that ballpoint pens leave a groove pattern on the paper at the moment of writing. However, this pattern is modified when another ball point pen crosses that line, making a "waisting" effect appear at the crossing region, like the narrowing feature described by Strach. Based on this fact, the author argued that Ultraviolet (UV)/visible/Near Infrared (NIR) photoluminescence techniques could highlight those patterns and allow a clear determination of the sequence of crossings. Nevertheless, this method is limited to ink lines that have different luminescent properties.

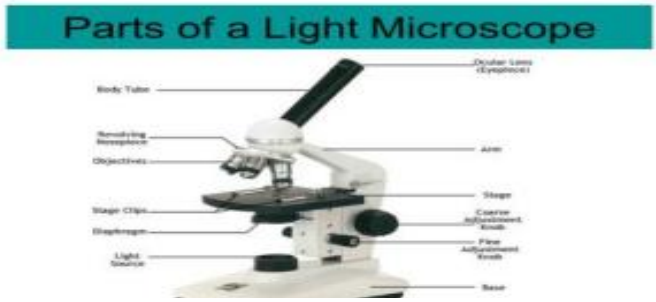
Singla et. al proposed a simple method for determining the sequence of crossings made with ball point pen ink lines and correctable carbon ribbon based on physical features like the absence or presence of sheen or gloss. A stereo micro scope with magnifications ranging from 20x to 50x were used and 45° angle illumination. The authors noticed a continuous sheen in the ballpoint pen ink line, including in the crossing region, when that ink was over the correctable carbon ribbon, but the sheen was interrupted in the crossing region in the opposite crossing order.

Oron and Tamir and Waeschle described the use of Scanning Electron Microscopy (SEM). Satisfactory

results were reported in crossings made between different types of inks, especially those in which the ink lines remain on the surface of the paper, such as pencil, ballpoint pen, rubber stamp and typewriter ribbon inks. On the contrary, crossings made with liquid pen inks, such as fibre-tip and fountain pens could not be successfully analysed with this method because these inks tended to penetrate the paper. Other disadvantages of SEM technique include its high cost, the need for vacuum and conductive surface, damage to the documents, the images obtained are only bidimensional, in black and white scale.

Kasas et al recommended use of Atomic Force Microscopy (AFM) to determine the sequence of crossings made with dot matrix printers (using new and worn black fabric ribbons) and black ballpoint pen inks. Differently from SEM, the AFM does not need a conducting sample or vacuum conditions. Results obtained by visual examination showed that when the pen ink line was over the printed line, the surface of the crossing was a dense and smooth layer. In the opposite order, the printer ribbon ink exhibited a granular appearance. Given this, the high-resolution images obtained with AFM technique and the different ink textures on the surface of the crossings allowed for a clear determination of the sequence of crossings. However, the method was subjective. A drawback of this method is that it only provides physical information from the surface and a very small area of the crossing.

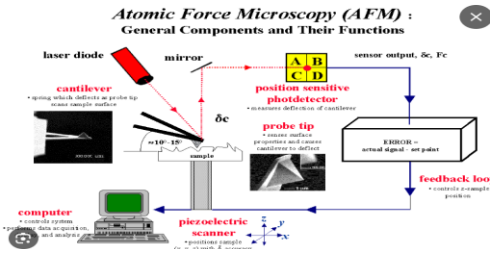
Cheng et.al. examined crossings made with ballpoint and Fiber-tip pen inks using a Laser Scanning Confocal Microscopy (LSCM). LSCM is a non-destructive technique in which a series of sectional areas are analysed by a laser beam and the images captured are overlapped and reconstructed by a computer. By changing the block filters and light source, the induced fluorescence from each ink may differ and this can be used to visualize and determine the sequence of crossings. the sequence of crossings could not be determined because they were inks of the same color and the LSCM technique could not detect fluorescence differences between them or they did not exhibit a clear fluorescence, for example, with the water-based



Stereo microscope is also called dissecting microscope is light illuminated. The image that appears is three dimensional. It is used for dissection to get a better look at the larger specimen. You cannot see individual cells because it has a low magnification).

light microscope/ optical microscope is an optical instrument which operates on the principal that light energy will pass through and around a suitably thin object, and with the aid of lenses form a magnified impression on the visual sensory layer of the eye.

*(SEM(scanning electron microscope)*use electron illumination. The image is seen in 3-D. It has high magnification and high resolution. The specimen is coated in gold and the electrons bounce off to give you an exterior view of the specimen. The pictures are in black and white)



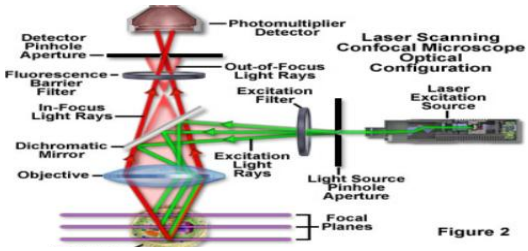
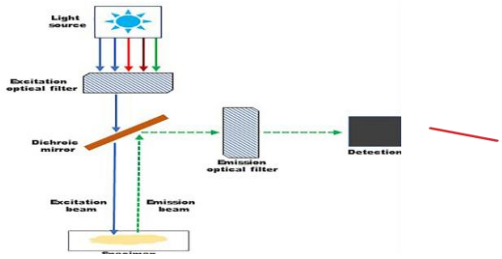


Figure 2



The Atomic Force Microscope works on the principle measuring intermolecular forces and sees atoms by using probed surfaces of the specimen in nanoscale

*Confocal Microscope*Coherent light emitted by the laser system (excitation source) passes through a pinhole aperture that is situated in a conjugate plane (confocal) with a scanning point on the specimen and a second pinhole aperture positioned in front of the detector (a photomultiplier tube).

Fluroscence microscopy : The specimen is illuminated with light of a specific wavelength (or wavelengths) which is absorbed by the fluorophores, causing them to emit light of longer wavelengths (i.e., of a different color than the absorbed light).

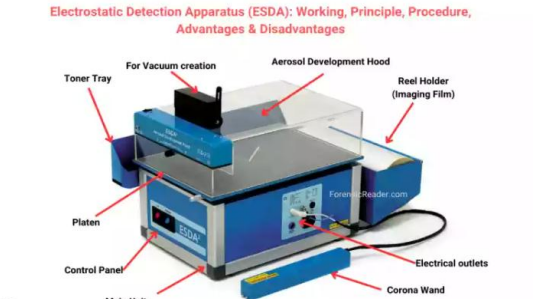
ESDA: It stands for Electrostatic Detection Apparatus. The ESDA has been manufactured by Foster and Freeman Ltd., It is an instrument used for questioned document examination to reveal the indentations or impressions.

Review study and observations:
Radley examined the sequence of writing indented impressions and ballpoint pen ink lines on different papers, with different writing pressures using the ESDA technique and a 4x magnification lens. The author observed that white marks from the pen ink lines dominated the crossing region when they were over dark marks from the writing indented impressions, while dark marks dominated in the opposite case.

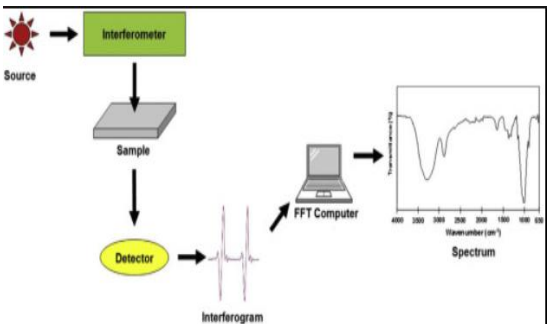
Giles published some results of the ESDA analysis under different experimental conditions, where more correct determinations were found when the white marks from pen ink lines were over the dark writing indented impressions, in contrast to Radley's paper. This author also examined crossings at different angles using ESDA and two persons used magnification with strong fluorescent lighting to visually examine samples in a blind trial. The influence of humidity changes on the samples was also tested by putting them in a water chamber before analysis, which yielded better results.

Radley continued researching the potential of the ESDA technique for the examination of the sequence of crossings between writing indented impressions and other types of pen inks besides ballpoint, such as Fiber-tip and rollerball pen inks, on two types of paper as well as on older paper samples such as notebooks and business documents. Additionally, crossing lines made at different angles and subject to different humidity conditions were examined, with a methodology similar to that proposed by Giles. In order to avoid erroneous interpretations due to striation patterns and broken ink lines, the author disregarded the samples in which the amount of ink was not deposited over the entire width of the line. The author concluded that even though the type and color of the ink had little effect on the performance of the method, continuous, broken, broad or narrow lines could strongly influence interpretation of results.

N. Nic Dae´id, L. Whitehead, M. Allen b conducted an experiment by selecting different kind of pens (ball point pen, gel pen and roller pen) and papers (with 80GSM, 100 GSM and low-quality sketch paper) to study the sequence. They expected that if the impressions were made on top of the writing there will be a higher percentage of dark dominance. The likelihood ratio values for white dominance are greater that when considering dark dominance indicating that this is a more reliable predictor of the sequence of the intersection. Authors concluded that, results are also affected by both paper quality and pen type.



Principle: The indented writing is visualized through the application of charge sensitive toner. Indented writing (i.e., disturbed fibers) created from previously written documents on overlying pages can then be seen. In some cases, this method can be applied to develop fingerprints on documents.



Principle of FTIR: When infrared radiation is bombarded on a sample, it absorbs the light and creates various vibration modes. The resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample.

FTIR and ATR-FTIR

FT-IR stands for Fourier Transform InfraRed, the preferred method of infrared spectroscopy. In infrared spectroscopy, IR radiation is passed through a sample. Some of the infrared radiation is absorbed by the sample and some of it is passed through (transmitted).

ATR-FTIR:

Attenuated total reflectance is the most widely used sampling methodology for Fourier transform infrared (FTIR) spectroscopy. ATR-FTIR quickly and easily measures a broad range of sample types, including liquids, solids, powders, semisolids, and pastes.

Review study and observation:

Katherine Bojko.et.al made experiment by using ZnSe ATR crystal in the large sampling accessory to determine the sequence of heterogeneous line intersections produced from ballpoint pens and laser printers using ATR-FTIR. The chief advantages of the technique it relies upon on chemical differences. experiment failed to image a number of writings/ printing materials on paper, including ink-jet printing, and various pens such as gel pens, roller ball pens, and felt-tip pens.

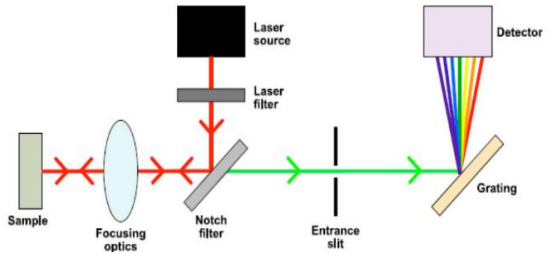
Raman Spectroscopy: It was named in the honour of its inventor, C.V. Raman, who, along with K.S. Krishnan, published the first paper on this technique Raman spectroscopy is a molecular spectroscopic technique that utilizes the interaction of light with matter to gain insight into a material's make up or characteristics, like FTIR.

Case study and observations:

Claybourn and M Ansell presented a method for analysing crossings made with black ballpoint pen inks using Raman depth analysis, which allows obtaining chemical information from within the crossing region.

Fabiańska and Kunicki analysed 208 crossing samples made with ballpoint, fibre-tip and rollerball pen inks of different colours, as well as 5 inkjet printers, using Raman spectroscopy. For study Forum 685-2 spectroscope with laser applied. The intersections were created on IBM Laser paper. The best results were obtained with crossings made with different writing instruments (heterogeneous crossings, as they named them). But this method is partially destructive as author burned the top of ink layer for experiment purpose.

S.I. Sharaa.et.al studied two types of overlapping were used to prepare samples of intersecting strokes. In the first intersection type, toner printed first then stamp pad ink crossed over it. In the second intersection type, stamp-pad ink stamped first then the toner printed over it. The toner and two kinds of stamp-pad ink(Mac red ink, Huhuablue ink) are subjected to Raman examination in two types of intersection. Author observed that, regardless of colour, sequence can be determined.



Principle: Raman spectroscopy is a scattering technique. It is based on Raman Effect, i.e., frequency of a small fraction of scattered radiation is different from frequency of monochromatic incident radiation. It is based on the inelastic scattering of incident radiation through its interaction with vibrating molecules. It probes the molecular vibrations.

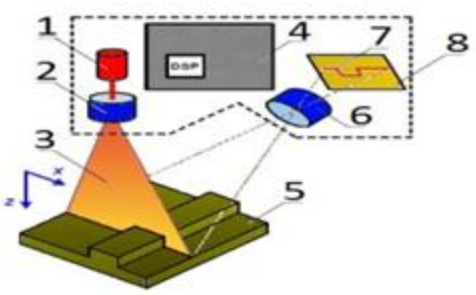
3D laser profilometry: Laser profilometry, as a non-contact technique, leaves the surface of the questioned documents unaltered. A UBM laser profilometer is used to measure the topography of the questioned documents. It is a non-contact technique that leaves the surfaces unaltered.

Review study and observation:

Heikkinen.et.al investigated the surface profiles of groove lines made with a scratching device onto a copper surface using a confocal microscope and a white-light scanning interferometer. The authors argued that these 3D imaging techniques could characterize deformations on surfaces of materials and therefore, be used to determine the sequence of crossing ink lines. Three types of intersections were prepared: the first groove was engraved with a lower normal force than the second, the first groove was engraved with a higher normal force, and the two grooves were engraved with similar normal force. The surface profile analysis was based on the continuity of the striae, presence of ridges from the second line and shifting of the deepest spot along the second grove (analysed based on the height profiles over the crossing area). Despite the fact that the method proposed can quantitatively measure the 3D surface profiles with sufficient accuracy, the authors failed to show the application to real crossing ink lines.

Giuseppe Schirripa Spagnolo proposed the use of 3D laser profilometry, realized by means of the conoscopic holography, to transform seemingly flat handwritten letters into landscapes of hills and valleys that reveal the pressure and stroke sequence used to create each word documents. this method is able of analysing the pressure variations used during the writing. The main potentiality over the ‘‘traditional’’ methods and is that it allows to determine, with success, the sequence intersection made by two mixed inks of similar colour (e.g. when the inks are chemically and optically mixed at the crossings). The principal limit is the inability to analyse intersection if the profile, left by the writing media, is similar to the mean roughness of the paper. Other limit is the time consumed to acquire data. For this reason, it is essential to carry out studies for the improvement of the used hardware.

Veerle Berx and Jan De Kinder analysed the crossing pen strokes using IDL. The non-homogeneous structure of the paper appears to be a complicating factor for analysis. Samples were prepared with a varying pen pressure and varying support. The obtained 3D graphs and 2D projections allow to distinguish three types of phenomena. One pen stroke is completely broken up by the second pen stroke, The first written line is inevitably intersected by the edge marks of the last written one. Authors observed the 'oval' structure is due to the additional impression left by the last written line leaves in the existing groove of the first pen stroke. A supplemental data-analysis was applied, based on the hypothesis that the morphology of the first written pen stroke is altered by the second line. The change in morphology would appear by a difference in width and depth of the first pen stroke inside and outside the actual crossing. both crossing lines were fit by means of a Gaussian. The evolution in width and depth throughout the crossings was evaluated for both lines in this paper.



Principle: The laser profilometry method is based on the processing of images of laser beams bent by the tested object profile. The figure depicts the simplest way to measure profile height. A narrow laser beam (1) passes through the diffraction module (2) and is converted into laser plane (3). The section of laser plane and tested object surface (5) is the tested object profile recorded by the camera (6). The profile image (7) made on the photosensitive matrix (8) is sent to the signal processor (4) where it is processed and the absolute millimetre dimensions of the object are calculated.

VSC (Video Spectral Comparator):
VSC designed by Foster and Freeman Ltd especially for document examination and contains in one unit all the techniques required to detect and record differences in inks on the documents.It is an integrated composite system comprising of cameras, various light sources which includes IR, Laser, UV etc. and filters which assist in comparison of questioned documents.

*Review study and observation*s:
Ridamjeet Kaur.et.al conducted experiment to determine the sequence of intersecting laser printer and typewriter ink strokes with strokes of writing inks by studying their absorption spectra generated through the Video Spectral Comparator (VSC-2000-HR). They obtained negative and inconclusive results in their study.

Angelica Rocha Martins.et.al conducted experiment with univariant and multivariant analysis with hyperspectral imaging of ball point pen inks using VSC 6000.Authors advised only blind tests which not given same results in real case examination.

R. Giri.et.al performed experiment to establish chronological order in crossing strokes between printed stroke and pen strokes. They made samples of crossing strokes on white photocopy paper. Video Spectral Comparator (VSC)-6000 is used to produce absorption spectra for studying chronological order of our samples of crossing lines. In case of homogeneous sample, they got negative result. But in heterogeneous samples got positive and conclusive result. they advised absorption spectra is not suitable to study homogeneous crossings as suggested by Kaur.

Reeta R. Gupta and Nassruddin conducted experiment to determine sequence of ball point pen inks using VSC 8000. Total seven samples including the actual questioned document were obtained. Six number of homogenous test samples were procured from different persons which were executed with ball point pens on A4 size sheet where two or more writing strokes were crossing over each other. Authors concluded that, it is useful if writing pressure uniformity has maintained.

*Principle:*Video Spectral Comparator (VSC) operates on light and electromagnetic radiation principles. In general, when light hits, there are numerous types of interactions such as reflection, absorption, transmission, luminescence that result in emitted wavelengths because of the composition of the object.

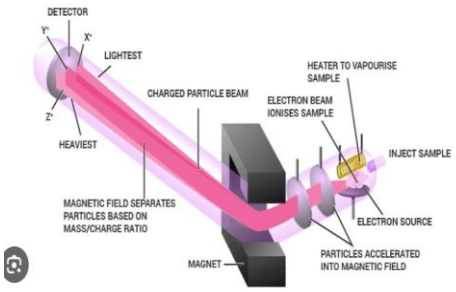
Mass spectrometry

Mass spectrometry, also called mass spectroscopy, analytic technique by which chemical substances are identified by the sorting of gaseous ions in electric and magnetic fields according to their mass-to-charge ratios.

Review study and observations:

Damila Rodrigues.et.al proposed an experiment fordetermination of crossing lines involvingstamp and pen inks by mass spectrometry imaging. Authors tested MS with Easy Ambient Sonic Spray ionization (EASI) in many investigations of forgery and adulteration.They first evaluated the effiency of EASI-MSI to study the correct order of deposition. Authors advised method is suitable determining the order of any crossing ink lines if the inks produced different ions.

Mason C. Malloy .et.al utilised Secondary Ion Mass Spectrometry using MeV ion excitation for the analysis of optically indistinguishable intersecting ballpoint pen lines on paper. A set of six blue ballpoint pens was collected from various sources for this experiment. From the point analysis of each pen, the characteristic peaks for each of the inks were determined from the MeV-SIMS spectra technique and was able to identify different colorants (dyes and synthetic organic pigments) with high efficiency and in a single measurement. The analysis of ink-ink intersections was performed using the Time-of-Flight mass spectrometer for MeV Secondary Ion Mass Spectrometry. Authors successfully studied sequence.



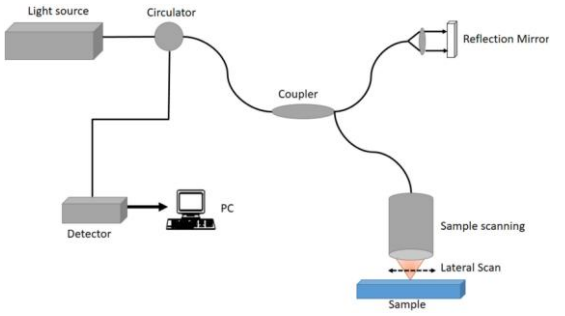
*Principle:*Mass spectrometry (MS) is an analytical technique that separates ionized particles such as atoms, molecules, and clusters by using differences in the ratios of their charges to their respective masses (mass/charge; m/z), and can be used to determine the molecular weight of the particles.

Optical Coherent Tomography:

Optical coherence tomography (OCT) and optical coherence tomography angiography (OCTA) are non-invasive imaging tests. They use light waves to take cross-section pictures of your retina.

Review study and observations:

Ning Zhang et.al used this technique to determine the sequence of intersecting lines between gel pens and seals.Two types of the seals were made with water-based stamp pad ink, and one was made with oil-based stamp pad ink. The main components of oil-based stamp pad ink are nonpolar solvents, mineral oils, vegetable oils, surfactants, pigments, resin oils, and oil-soluble dyes. The water-based stamp pad ink is composed of polar solvents,water-soluble resin, and water-soluble dyes. All intersecting line samples (including blind testing) were formed on A4 size white papers with a basis weight of 70 g/m2.Three common types of red seals and black gel pens were prepared to produce heterogeneous intersecting line samples. However, there has been no related study on determining the sequence of intersecting lines by OCT. In this study, OCT technology is proposed to determine the sequence of intersecting lines for the first time, which provides a novel and reliable technique for document examination. This study focuses on the examination of the sequence of intersecting lines between stamp pad seal ink and gel pen ink that remains a difficult problem because of the characteristics of water-based ink.2D cross-sectional and 3D volumetric OCT images were obtained to perform the feature comparison and analysis. A total of 12 blind tests were conducted by the authors to demonstrate the effectiveness of OCT technique and the light absorption of the ink would affect the accuracy of examination. The results from this preliminary study demonstrated that OCT can be very useful in determining the sequence of intersecting lines between gel pens and stamp pad ink seals.



Principle: The principle of OCT is low coherence interferometry.

CONCLUSION

This comprehensive review springs limelight on techniques used by different authors in determination of sequence of crossing ink lines. Numerous parameters such as ink composition, ink polarity, writing pressure and writing speed, humidity factor, skipping and striations in case of ball point ink, quality of the paper, time gap for preparation has to be cautiously chosen for the better results. Non-destructive techniques are suitable over destructive techniques to maintain the usage of documents for further investigations. Study of morphology, spatial characteristics can be studied using 3D view. Heterogeneous ink study given conclusive results over homogeneous mixture.

FUTURE SCOPE

Determination of crossing ink lines and determination of age of ink are inter relatable. Ink line crossing at a fold has certain definite characteristics. Advanced tools such as Hyper Spectral Imaging technique, PLS DA tool may be used for further study for homogeneous ink crossings.

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