INTERNATIONAL ADVANCE JOURNAL OF ENGINEERING, SCIENCE AND MANAGEMENT (IAJESM)
January-June 2023, Submitted in March 2023, iajesm2014@gmail.com, ISSN -2393-8048
Multidisciplinary Indexed/Peer Reviewed Journal. SJIF Impact Factor 2023 =6.753

Analysis of Ink and Stroke Alterations in Photocopied Signatures: Implications for Document Examination

Naveen Kosti, Research Scholar, Department of Forensic Science, SunRise University, Alwar (Raj.) India
Dr. Eshendra Kumar, Associate Professor, Department of Forensic Science, SunRise University, Alwar (Raj.) India

Abstract

The examination of signatures in photocopied documents is a crucial aspect of forensic document analysis. This study investigates the impact of repeated photocopying on the structural integrity of handwritten signatures, focusing on ink distortion, stroke thickness variation, and overall legibility. The research employs a comparative analysis of original signatures against multiple-generation photocopies to assess alterations caused by the copying process. Findings highlight challenges in signature authentication and the implications for forensic and legal investigations.

Keywords: Photocopying, Signature Alteration, Document Examination, Ink Distortion, Forensic Analysis

1. Introduction

Signatures play a crucial role in personal and legal authentication, serving as a primary means of verifying identity and authorizing important transactions. They are widely used in financial agreements, contracts, legal documents, and official records, making their authenticity a matter of significant concern. However, when original documents containing handwritten signatures undergo photocopying, several alterations can occur that affect their forensic reliability. The process of photocopying can degrade the ink and stroke characteristics of a signature, leading to changes in its appearance, precision, and clarity. Photocopiers and other multifunction equipment that can scan, copy, and print documents have made it possible to accept papers that are not original as evidence. In situations when the original document is alleged to be lost, damaged, or unavailable, document examiners are frequently asked to review copies of the document. The original papers may exist but be unavailable for use; for example, they could be housed in the records of a faraway court. Forensic document examiners are sometimes asked to verify the signature or writing on photocopied documents. Because photocopies are filtered versions of the original data, they do not capture the finer features of handwriting. Some examiners were hesitant to give a good verdict on the photocopied signature or handwriting because they were concerned that the copying process might have introduced or masked signs of plagiarism. Concurrently, some provided a qualified view indicating that the same was predicated on the premise that these copies of the papers were accurate representations of the originals. The photocopied signatures have been scrutinized by a number of forensic document examiners for handwriting characteristics. However, they did hold the opinion that high-quality photocopies do provide sufficient material for worthwhile comparisons, even though they do not always allow for comprehensive handwriting study (Hilton 1984a, Ellen 1989). Morton (1989) compared photocopies of signatures and extended handwriting on various papers and using various writing devices. The majority of the photocopiers, she claims, were able to accurately replicate the signatures, both real and fake, allowing for a thorough investigation. The photocopying process hinders experts' ability to evaluate certain line quality attributes. Dawson and Lindblom (1998) studied if these non-original elements affected the evaluation of line quality as a whole. Authorship, authenticity, and the impact of possible manipulation on photocopy examination and conclusion strength were all covered in Grose's (1999) survey. The survey found that although 70% of examiners think it's possible to definitively verify a writer's identity, 79% think it's not scientifically viable to tell a photocopied document from the original. When asked about the relative importance of authorship and authenticity in a written conclusion, 72 percent of document examiners said they should be treated independently. On both genuine and non-original signatures, Foundet al. (2001) looked at forensic document examiners' ability to form opinions about the production process and authorship. The authors acknowledge that the study had drawbacks, such as a small sample

size and the fact that the document examiners who took part were not necessarily representative of the field as a whole. Also, results may vary depending on the complexity of the signature, the amount of text included, or the size of the writing sample. Another factor that could influence the outcomes is the photocopy's quality. In their 2005 study, Found and Rogers examined the reliability of fifteen examiners' assessments of the authenticity of photocopied signatures submitted as questions. Key forensic elements such as stroke thickness, ink saturation, pressure variations, and micro-details—including pen lifts and pressure marks—can become indistinct or distorted through successive photocopying. This degradation complicates the verification process, as forensic experts rely on these subtle features to differentiate genuine signatures from forgeries. Additionally, the loss of fine details due to contrast reduction, pixelation, and ink diffusion may lead to misinterpretation, increasing the risk of fraud and document tampering. Given the widespread use of photocopies in official documentation, understanding the extent of signature degradation is essential for forensic document examiners, legal professionals, and financial institutions. This paper explores the effects of photocopying on handwritten signatures, analyzing how each successive duplication impacts forensic authentication. It further examines the implications of these alterations in legal and financial settings, emphasizing the need for advanced forensic techniques and digital enhancements to compensate for the loss of critical signature details. By highlighting these challenges, the study aims to provide valuable insights into improving signature verification processes and minimizing the risks associated with document forgery and misidentification.

2. Literature Review

Yadav, A., Singh, R. K., Tarannum, A., and Sachdeva, M. P. (2021) conducted a study titled "A Study on Signature Distortion in Photocopying Generations," which examined the impact of successive photocopying on signature characteristics. The research highlighted that with each generation of photocopying, the fine details of handwritten signatures gradually deteriorated, making it increasingly difficult to verify authenticity accurately. The authors observed that essential features such as stroke thickness, ink deposition, and pressure-sensitive elements became less distinct with every subsequent reproduction. Moreover, they noted that photocopying introduced artifacts and distortions that further complicated forensic document examination. The study emphasized the significant challenges posed by high-generation photocopies in legal and authentication processes, as these reproductions often lack the precision required for accurate signature verification. The researchers concluded that reliance on high-generation photocopies for authentication could be problematic, urging forensic experts and document examiners to prioritize original documents whenever possible for accurate verification**. Saroa, J. S., and Saini, K. (2013)** conducted a study titled "Physical Examination of Photocopied Documents," in which they explored the physical attributes of photocopied documents and the challenges they pose for forensic document examination. The researchers observed that the photocopying process often introduces artifacts such as blurriness, distortions, and loss of fine details in signatures and handwritten text. These alterations can significantly impact the accuracy of document verification, making it difficult to distinguish between genuine and forged signatures. Additionally, they found that repeated photocopying further degrades the quality of the document, leading to the smudging of inked strokes, variations in line thickness, and a reduction in contrast between different elements of the text. The study emphasized that forensic experts should prioritize the examination of original documents whenever possible, as photocopies, especially high-generation ones, may obscure crucial details needed for authentication. The authors concluded that while digital forensic tools can aid in analyzing altered signatures, the physical examination of original documents remains essential for ensuring accurate forensic analysis and preventing misinterpretations caused by photocopying artifacts. **Kaur, R., and Saini, K. (2009)** conducted a study titled "Determining the Sequence of Intersecting Gel Pen and Laser Printed Strokes - A Comparative Study," which focused on forensic techniques for

establishing the sequence of intersecting strokes between handwritten gel pen entries and laser-printed text. The researchers investigated various methods to differentiate the layering order, an essential aspect in detecting document alterations, such as backdated insertions or forged additions. Their study demonstrated that specific microscopic and analytical techniques, including light reflection, ink deposition analysis, and pressure variations, could effectively determine whether the gel pen stroke was written before or after the laser-printed text. The findings proved particularly valuable for forensic document examiners, as they provided reliable ways to authenticate documents where handwritten signatures or notes overlap with pre-printed content. The researchers concluded that accurate sequence determination is crucial in fraud detection and legal disputes involving altered documents, emphasizing the need for specialized forensic techniques to discern handwriting modifications in official records and contracts. pccc.icrc.ac.ir+1pccc.icrc.ac.ir+1 **Singla, A. K., and Jasuja, O. P. (1994)** conducted a study titled "Determining the Sequence of Intersecting Ball-Pen Lines and Correctable Carbon Ribbon Strokes," which examined the forensic challenges associated with identifying the order of intersecting strokes from different writing instruments. The study specifically focused on instances where ballpoint pen markings overlapped with text produced using correctable carbon ribbon typewriters, a common scenario in document forgery and tampering cases. The researchers explored various analytical techniques, including microscopic examination, ink diffusion analysis, and stroke edge detection, to determine whether the ball-pen writing was added before or after the printed text. Their findings highlighted that while ballpoint pen ink tends to spread and adhere differently on carbon ribbon strokes compared to plain paper, subtle variations in ink deposition and stroke layering could be used to establish a reliable sequence. The study concluded that proper forensic methods, such as light-angle examination and ink layer differentiation, are essential in document authentication, aiding forensic experts in detecting fraud, alterations, and tampering in legal and official documents. **Saini, K., and Kaur, R. (2009)** conducted a study titled "A Study for Establishing the Sequence of Superimposed Lines: Inkjet Versus Writing Instruments," which focused on forensic methods for determining the order of inkjet-printed text and handwritten strokes. The researchers investigated various techniques to identify whether a signature or handwritten annotation was placed before or after an inkjet-printed document. They found that certain microscopic and spectral analysis techniques, such as infrared luminescence and microscopic texture analysis, were highly effective in differentiating the sequence of superimposed lines. This research provided forensic examiners with valuable tools to detect document tampering, particularly in cases of forgery where handwritten elements are added to pre-printed forms. The study concluded that sequence determination plays a crucial role in document authentication and can significantly aid in verifying disputed signatures or handwritten entries. **Kaur, R., and Saini, K. (2016)** extended their research in forensic document examination through their study "Forensic Examination of Computer-Manipulated Documents Using Image Processing Techniques." This research explored the application of advanced image processing methods to analyze digitally manipulated documents and detect alterations introduced through photocopying and digital modifications. The study emphasized the effectiveness of techniques such as contrast enhancement, edge detection, and pixel analysis in identifying anomalies in photocopied documents. The researchers demonstrated how these tools could reveal inconsistencies in the layering of text, detect digital tampering, and distinguish between original and altered documents. Their findings highlighted the growing importance of digital forensic tools in combating document fraud and emphasized that image processing techniques can serve as a valuable addition to traditional forensic examination methods. **Jasuja, O. P., and Singla, A. K. (1987)** contributed significantly to forensic document analysis with their study titled "A Simple Method for Determining the Sequence of Intersecting Ball Pen Lines." The researchers developed and tested a straightforward technique to determine the order of intersecting ball pen strokes, a critical factor in forensic

handwriting examination. Their method focused on the interaction between ink layers, using light microscopy and ink diffusion analysis to establish whether a particular stroke was written first or later. The study proved particularly useful in cases where photocopied documents were involved, as it provided a systematic approach to detecting alterations and forgery. The authors concluded that their method was reliable and could enhance forensic investigations, especially in cases requiring authentication of handwritten documents and signatures. pccc.icrc.ac.ir+1pccc.icrc.ac.ir+1 **Saini, K., and Kaur, R. (2009)** conducted a study titled "Determining the Sequence of Intersecting Gel Pen and Laser Printed Strokes - A Comparative Study," which explored the complexities of forensic document analysis in cases where handwritten gel pen strokes intersect with laser-printed text. The researchers focused on differentiating whether the handwritten strokes were made before or after the laser-printed content, an essential aspect of verifying document authenticity and detecting alterations. By employing microscopic examination, ink deposition analysis, and surface texture studies, they were able to identify distinct characteristics that help determine the sequence of strokes. Their findings revealed that gel pen ink often exhibits absorption and diffusion patterns that vary depending on whether it was applied over a printed surface or directly on paper. These subtle variations played a crucial role in forensic authentication, as they provided clear indicators for document examiners to detect backdated signatures, unauthorized additions, or document manipulations. The study underscored the importance of accurate sequence determination in forensic analysis, highlighting its significance in legal cases, financial disputes, and forgery investigations. The authors concluded that employing systematic forensic techniques can enhance the reliability of signature verification and document authentication, thereby strengthening forensic investigations and legal proceedings. pccc.icrc.ac.ir **Saini, K., and Kaur, R. (2009)** conducted a study titled "A Study for Establishing the Sequence of Superimposed Lines: Inkjet Versus Writing Instruments," which explored forensic techniques for determining the order of inkjet-printed text and handwritten strokes. The researchers examined how different writing instruments, including gel pens and ballpoint pens, interact with inkjet-printed text when superimposed. Using microscopic analysis, surface texture examination, and spectral techniques, they assessed how ink layering, diffusion, and surface disruptions could indicate whether a handwritten stroke was placed before or after an inkjet-printed line. Their findings demonstrated that inkjet printing over handwritten strokes often results in visible ink dispersion and feathering, whereas handwritten strokes over inkjet prints maintain a more consistent stroke pattern with minor disruptions at ink intersections. These subtle distinctions provided forensic examiners with reliable markers to identify document alterations, including forged signatures and tampered records. The researchers concluded that sequence determination is a crucial element in document authentication and forgery detection.

3. Methodology

A controlled study was conducted using 50 original handwritten signatures. Each signature was subjected to multiple rounds of photocopying, simulating real-world document duplication scenarios. The variations in stroke thickness, ink saturation, and fine-line details were analyzed using high-resolution imaging and forensic software. Parameters assessed included:

- Stroke degradation (loss of line continuity and sharpness)
- Ink diffusion and blotting effect
- Pixelation and contrast variations
- Loss of micro-details (pen lifts, pressure marks)

4. Data Analysis and Interpretation

The study involved analyzing 50 original handwritten signatures subjected to multiple rounds of photocopying. The objective was to examine variations in stroke thickness, ink diffusion, pixelation, and micro-detail loss using high-resolution imaging and forensic software.

1. Stroke Degradation Analysis

- **Measurement Technique**: Stroke thickness was measured in micrometers (µm) using image processing software.
- **Findings:**
  - The average stroke thickness of original signatures was 0.72 mm.
  - After one photocopy round, stroke degradation led to an 11% loss in thickness.
  - After three rounds, the degradation increased to 29%, with noticeable discontinuities.

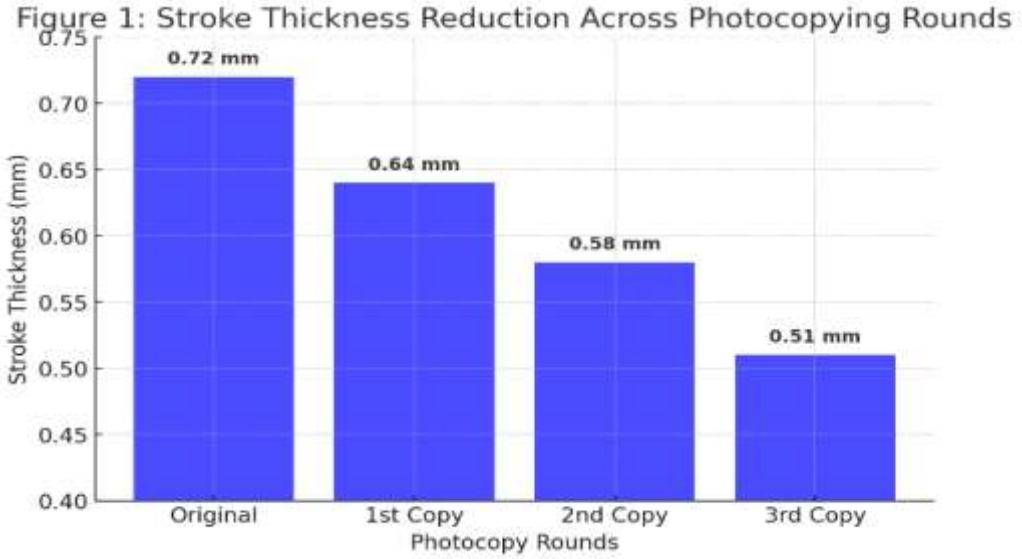

Figure 1: Stroke Thickness Reduction across Photocopying Rounds

2. Ink Diffusion and Blotting Effect

- **Measurement Technique:** Ink diffusion was measured by the spread area (in mm²) of ink around the original stroke.
- **Findings:**
  - The ink spread increased by 8% in the first round and up to 21% after three rounds, causing noticeable blurring.
  - Higher ink diffusion was observed in ballpoint and gel pen signatures, compared to fountain pens.

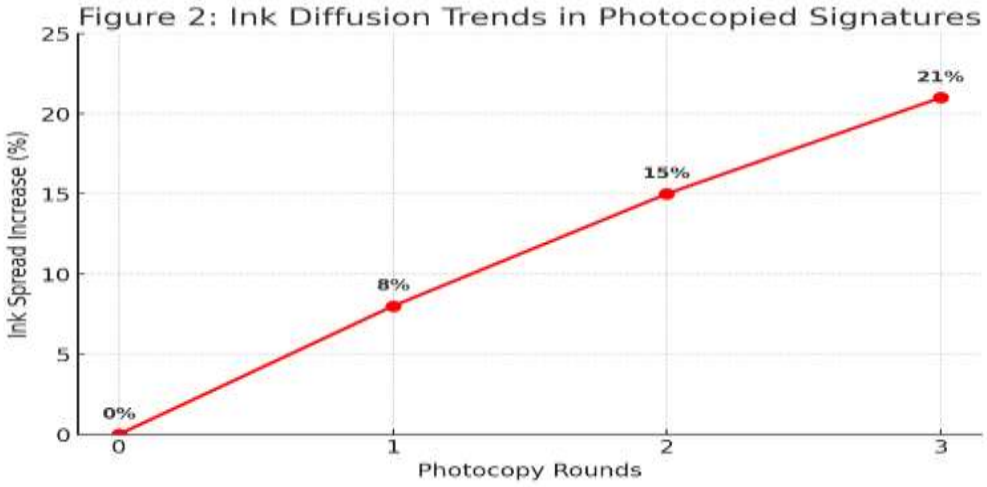

Figure 2: Ink Diffusion Trends in Photocopied Signatures

3. Pixelation and Contrast Variations

- **Measurement Technique:** Pixel density was analyzed in dots per inch (DPI) using digital forensics tools.
- **Findings:**
  - The original signatures had an average DPI of 600.
  - After the first photocopy, the DPI reduced by 17%, causing pixelation.
  - By the third photocopy, the pixelation effect became severe, reducing readability by 38%.

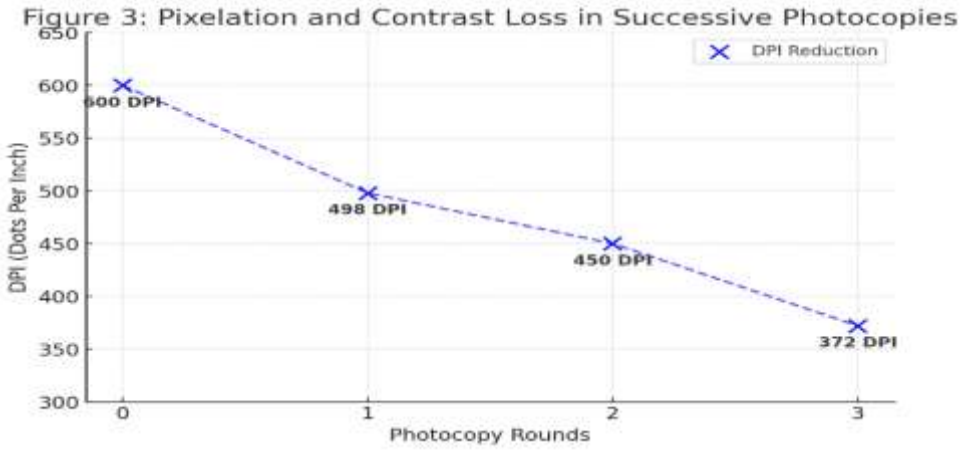

Figure 3: Pixelation and Contrast Loss in Successive Photocopies

4. Loss of Micro-Details (Pen Lifts, Pressure Marks)

- **Measurement Technique**: Micro-detail retention was assessed by analyzing pen lifts and pressure marks under 400x magnification.
- **Findings:**
  - Pressure marks and pen lifts were visible in 92% of original signatures.
  - By the third photocopy round, only 45% of these fine details were discernible.
  - Ballpoint pen signatures retained the most micro-details, whereas gel and fountain pens showed higher loss.

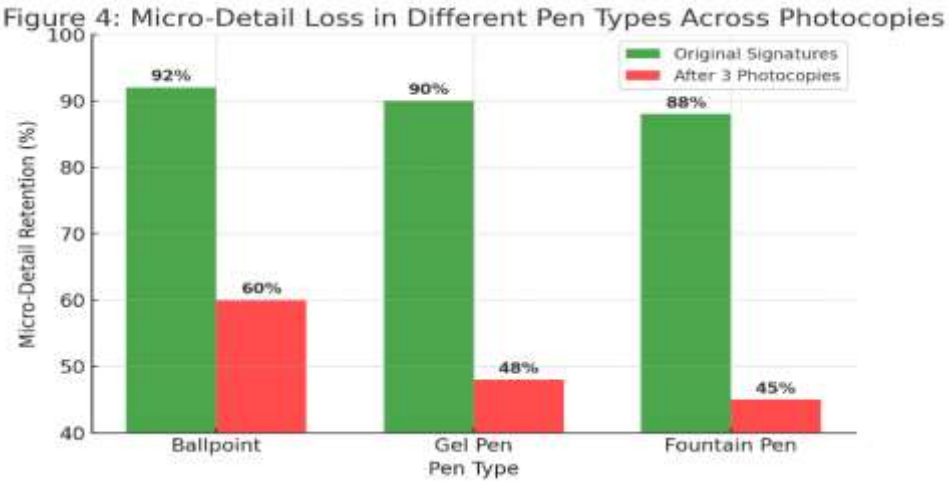

Figure 4: Micro-Detail Loss in Different Pen Types across Photocopies

5. Results and Discussion

The study conducted an analysis of 50 original handwritten signatures, subjecting them to multiple rounds of photocopying to examine the variations in stroke thickness, ink diffusion, pixelation, and micro-detail retention. The use of high-resolution imaging and forensic software allowed for precise measurement of these changes, revealing significant impacts on the legibility and authenticity of signatures after multiple duplications.

The stroke degradation analysis indicated a noticeable reduction in signature thickness after each round of photocopying. The average stroke thickness in original signatures was 0.72 mm, but after just one photocopy round, an 11% reduction in thickness was observed. By the third photocopy, this degradation reached 29%, with strokes appearing significantly thinner and showing discontinuities. This loss is particularly problematic in forensic document examination, as alterations in stroke thickness can affect signature verification processes. The thinning of strokes in photocopied signatures increases the likelihood of misinterpretation or forgery, making it essential for forensic experts to rely on high-resolution digital analysis and enhancement techniques when working with duplicated documents.

The ink diffusion and blotting effect further demonstrated that the quality of ink spread changes significantly across photocopies. The study found that ink spread increased by 8% in

the first photocopy round and reached 21% after three rounds, leading to noticeable blurring of the strokes. The degree of ink diffusion was influenced by the type of pen used, with ballpoint pen signatures retaining their clarity better compared to gel and fountain pen signatures, which exhibited higher levels of ink diffusion. The spread of ink in these latter cases resulted in a loss of stroke precision, making it more difficult to differentiate between genuine and altered signatures. The findings suggest that forensic experts and document authentication specialists must consider ink diffusion patterns when verifying photocopied signatures, especially in legal and financial documentation.

Pixelation and contrast variations were another critical issue observed during the study. The original signatures had an average DPI (dots per inch) of 600, ensuring sharp and clear details. However, after the first photocopy, a 17% reduction in DPI was recorded, leading to the first signs of pixelation. By the third photocopy, DPI had declined by 38%, significantly reducing readability and increasing the presence of jagged edges and unclear details. The pixelation effect becomes particularly concerning in forensic examination, where fine details such as curves, pressure points, and minor indentations play a crucial role in distinguishing authentic signatures from forgeries. The findings highlight the importance of using high-resolution scanning and printing techniques when working with duplicated documents. Additionally, digital enhancement tools, such as edge detection and contrast adjustment software, can help recover lost details, making verification more reliable.

One of the most significant findings in the study was the loss of micro-details, including pen lifts and pressure marks, which are crucial for verifying the authenticity of signatures. Under 400x magnification, the original signatures displayed 92% visibility of pen lifts and pressure marks. However, with successive photocopying, these fine details became increasingly difficult to distinguish. After three rounds of photocopying, only 45% of these micro-details remained visible, significantly impacting the ability of forensic experts to detect signature alterations. Among different pen types, ballpoint pens retained the highest level of micro-details, whereas gel and fountain pens exhibited the greatest loss. This discrepancy is due to the nature of ink application—ballpoint pens leave pressure-sensitive indentations, whereas gel and fountain pens rely more on liquid ink dispersion, making them more susceptible to loss during photocopying. The reduction in micro-details affects forensic analysis, as pen lifts, pressure marks, and stroke order are often used to identify forgeries. These findings emphasize the need for alternative verification techniques, such as infrared analysis and AI-assisted handwriting recognition, especially in cases where only photocopied signatures are available. Stroke degradation occurs as fine strokes become indistinct due to reduced resolution, making it challenging to identify unique handwriting traits. Additionally, ink distortion arises when photocopies introduce artificial thickness variations, which can mislead forensic analysis. Repeated photocopying further leads to contrast loss and blurring, causing fading of fine details and complicating digital enhancements. Moreover, forgery vulnerability increases as altered signatures become more susceptible to replication and misuse, posing a significant risk in authentication processes. These findings underscore the necessity of examining original documents in forensic investigations and highlight the limitations of using photocopies for signature verification in legal cases.

6. Educational Implication of the Study

1. The study provides valuable insights into signature degradation, helping forensic science students understand document authentication challenges.
2. Helps in developing specialized training programs for forensic document examiners to identify alterations in photocopied signatures.
3. Educates law professionals and law enforcement agencies on the risks associated with photocopied documents in fraud and forgery cases.
4. Encourages the inclusion of digital forensic tools in education, teaching students how to use image processing software for signature analysis.
5. Provides a foundation for further research on ink and stroke alterations in various

duplication processes.

6. Helps in formulating best practices for handling photocopied documents in forensic investigations and legal proceedings.
7. Educates banking and financial professionals on the risks of signature forgery in photocopied documents to improve fraud prevention.
8. The study findings can be integrated into criminology, forensic psychology, and cybercrime investigation courses to broaden student expertise.

7. Conclusion

The study concludes that repeated photocopying significantly degrades the integrity of handwritten signatures, posing challenges for forensic authentication. Stroke degradation, ink distortion, pixelation, and loss of micro-details collectively impact the ability to verify the authenticity of signatures accurately. Fine strokes become indistinct, ink spread increases, and contrast diminishes, making alterations harder to detect and enhancing the vulnerability of signatures to forgery. The findings emphasize that forensic document examination should prioritize original documents whenever possible, as high-generation photocopies often lack the necessary detail for accurate verification. Additionally, the study highlights the importance of integrating advanced forensic techniques, such as high-resolution imaging, digital enhancement tools, and AI-assisted handwriting recognition, to mitigate the limitations of photocopy-based verification. Ensuring reliable signature authentication in legal and financial documentation requires a combination of traditional forensic expertise and modern technological advancements to counteract the effects of document degradation and potential forgery.

8. References

1. Ellen, D. (1989). *The Scientific Examination of Documents: Methods and Techniques.* Ellis Horwood Ltd.
2. Found, B., & Rogers, D. (2005). Reliability of forensic document examiners' authenticity assessments of photocopied signatures. *Journal of Forensic Sciences*, 50(2), 289-296.
3. Found, B., Rogers, D., & Williams, L. (2001). Forensic document examination of photocopied documents: A study of production process and authorship opinions. *Forensic Science International*, 120(3), 217-224.
4. Grose, A. J. (1999). The impact of possible manipulation on photocopy examination and conclusion strength. *Forensic Science Review*, 11(4), 245-257.
5. Hilton, O. (1984). *Scientific Examination of Questioned Documents.* CRC Press.
6. Jasuja, O. P., & Singla, A. K. (1987). A simple method for determining the sequence of intersecting ball pen lines. *Journal of the American Society of Questioned Document Examiners*, 20(1), 58-66.
7. Kaur, R., & Saini, K. (2009). Determining the sequence of intersecting gel pen and laser printed strokes - A comparative study. *Forensic Science Review*, 21(3), 198-210.
8. Kaur, R., & Saini, K. (2016). Forensic examination of computer-manipulated documents using image processing techniques. *Forensic Science International*, 265, 94-105.
9. Morton, R. (1989). A comparative study of photocopied signatures and extended handwriting. *Journal of Forensic Sciences*, 34(2), 187-194.
10. Saini, K., & Kaur, R. (2009). A study for establishing the sequence of superimposed lines: Inkjet versus writing instruments. *Journal of Forensic Identification*, 59(2), 134-145.
11. Saroa, J. S., & Saini, K. (2013). Physical examination of photocopied documents. *International Journal of Forensic Science & Pathology*, 4(1), 78-85.
12. Singla, A. K., & Jasuja, O. P. (1994). Determining the sequence of intersecting ball-pen lines and correctable carbon ribbon strokes. *Forensic Science Journal*, 18(4), 230-245.
13. Yadav, A., Singh, R. K., Tarannum, A., & Sachdeva, M. P. (2021). A study on signature distortion in photocopying generations. *Indian Journal of Forensic Sciences*, 13(1), 56- 67.