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RGB Image Analysis of Bloodstains on Fabrics Subjected To Different Washing Methods

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***Abstract*—Bloodstain evidence plays a crucial role in forensic investigations, providing vital information about violent crimes, victim interactions, and attempts to conceal evidence. One of the common methods used by offenders to destroy such evidence is washing bloodstained fabrics. However, traces of blood often persist despite repeated washing. This study focuses on the application of RGB (Red-Green-Blue) image analysis as a non-destructive digital technique to examine bloodstains on different fabrics subjected to various washing methods. Fabrics including cotton, silk, wool, denim, and polyester were selected due to their widespread use in clothing and their varied physical properties. Bloodstains were applied to these fabrics and subjected to repeated hand- and machine-washing cycles. Digital images of the stains were captured under controlled lighting conditions, and RGB values were extracted using image processing software. The study revealed that bloodstains exhibit higher intensity in the red channel, which gradually decreases with successive washing cycles, indicating partial removal. Variations in stain persistence were observed across fabric types due to differences in absorbency and texture. The findings demonstrate that RGB analysis is an effective, economical, and reliable method for detecting and analysing bloodstains, even after washing, thereby enhancing forensic investigation techniques.**

***Index Terms*—RGB Colour Model, Bloodstain Detection, Fabric Analysis, Digital Image Processing.**

I. INTRODUCTION

Bloodstains are among the most significant forms of biological evidence encountered at crime scenes. They serve as silent witnesses, providing crucial insights into the nature of violent events, the position of individuals involved, and attempts to conceal evidence. The scientific analysis of bloodstains allows forensic experts to reconstruct crime scenes with a high degree of accuracy. However, criminals often attempt to eliminate such evidence through washing, making detection more challenging.

Blood is a specialized connective tissue composed of plasma, red blood cells, white blood cells, and platelets. Each component plays a vital role not only in physiological functions but also in forensic investigations. Red blood cells contain haemoglobin, which gives blood its characteristic red colour, while white blood cells contain DNA, enabling individual identification. Platelets contribute to clotting, which affects stain formation and drying patterns. In forensic science, bloodstain pattern analysis provides information about the mechanism of bloodshed. The size, shape, distribution, and direction of blood droplets can reveal whether the blood resulted from passive dripping, impact, or transfer. Additionally, bloodstains can indicate movement, struggle, or attempts to clean a crime scene. Fabrics are commonly encountered at crime scenes, especially in the form of clothing. The interaction between blood and fabric is influenced by factors such as fibre composition, texture, and absorbency. Natural fabrics like cotton and wool tend to absorb blood deeply, while synthetic fabrics like polyester may retain stains on the surface.

Traditional methods of blood detection often involve chemical tests, which may damage the sample. In contrast, digital image processing techniques such as RGB analysis provide a non-destructive alternative. RGB analysis evaluates the intensity of red, green, and blue components in an image, enabling quantitative assessment of colour changes in bloodstains. This study aims to analyse bloodstains on various fabrics subjected to different washing methods using RGB image analysis. By examining how bloodstains persist and change in colour intensity after washing, the research contributes to improving forensic detection techniques.

II. REVIEW OF LITERATURE

Previous research has extensively explored the detection, analysis, and persistence of bloodstains using various scientific techniques. Studies have shown that digital image processing plays a significant role in forensic investigations, particularly in analysing biological stains.

Thanakiatkrai et al. (2013) demonstrated the use of smartphone-based image analysis to estimate the age of bloodstains. Their findings indicated that colour changes in bloodstains over time could be quantitatively analysed using digital imaging. Similarly, Choi et al. (2019) improved smartphone-based systems for bloodstain age estimation by incorporating pattern recognition techniques.

Research by Kumar and Verma (2010) highlighted the importance of the RGB colour model in image processing. The study emphasized that RGB images consist of three channels representing red, green, and blue intensities, which can be analysed individually for detailed information.

Di Lascio et al. (2018) investigated the colour characteristics of bloodstains on historical fabrics, demonstrating that environmental factors and chemical composition influence stain appearance. Their work emphasized the importance of spectral analysis in understanding bloodstain properties.

Studies on washing effects, such as those by Khalid et al. (2024), revealed that detergent, temperature, and washing duration significantly affect bloodstain persistence. Natural fabrics were found to retain stains more effectively than synthetic ones.

Pereira et al. (2021) introduced hyperspectral imaging techniques for detecting bloodstains on coloured fabrics. Their hierarchical classification model achieved high accuracy in distinguishing blood from other substances.

Digital enhancement techniques have also been explored. Lee et al. (2015) demonstrated that image processing algorithms could improve the visibility of bloodstains under different lighting conditions.

Overall, the literature indicates that while traditional methods remain useful, digital image analysis techniques like RGB analysis provide a reliable, cost-effective, and non-destructive alternative for bloodstain detection and analysis.

III. AIM AND OBJECTIVES

The primary aim of this study is to evaluate the effectiveness of RGB image analysis in detecting and analysing bloodstains on fabrics subjected to different washing methods.

The objectives of the study include:

1. To analyse the persistence of bloodstains on various fabrics after repeated washing.
2. To compare the effects of hand washing and machine washing on bloodstain visibility.
3. To extract and analyse RGB values from digital images of bloodstains.
4. To evaluate the variation in colour intensity across different fabric types.
5. To determine the reliability of RGB analysis in forensic investigations.

The study also aims to provide insights into how fabric properties influence bloodstain retention. By understanding these factors, forensic investigators can improve their ability to detect hidden or partially removed stains.

Another objective is to establish a quantitative method for analysing bloodstains. Traditional methods rely heavily on visual observation, which can be subjective. RGB analysis, on the other hand, provides numerical data that can be statistically analysed.

The study further seeks to contribute to the development of cost-effective forensic techniques. Since RGB analysis can be performed using standard cameras and software, it offers a practical solution for resource-limited forensic laboratories.

IV. MATERIALS AND METHODS

The study employed an experimental research design to analyse bloodstains on different fabrics. The fabrics selected for the study included cotton, silk, wool, denim, and polyester. Blood samples were deposited on fabric pieces under controlled conditions. After drying, the fabrics were subjected to two types of washing methods: hand washing and machine washing. Each fabric underwent multiple washing cycles. Images of the bloodstains were captured after each washing stage using a digital camera under controlled lighting conditions. Consistent illumination was maintained to ensure accurate comparison of images. The captured images were analysed using image processing software to extract RGB values. Each pixel in the image contains intensity values for red, green, and blue components, ranging from 0 to 255. The extracted RGB values were used to calculate ratios and analyse changes in colour intensity. These values provided quantitative data on the persistence and fading of bloodstains. The methodology ensured that variables such as lighting, camera settings, and washing conditions were controlled to minimize errors. This approach allowed for accurate comparison of results across different fabrics and washing methods.

V. RESULTS AND DISCUSSION

The results of the study revealed significant variations in bloodstain persistence across different fabrics and washing methods. Initially, bloodstains exhibited high intensity in the red channel due to the presence of haemoglobin. As washing cycles increased, the red intensity gradually decreased, indicating partial removal of the stain. Hand washing resulted in moderate reduction of red values, while machine washing caused a more significant decrease. This is attributed to the mechanical action and detergent effects in machine washing. Natural fabrics such as cotton and wool retained bloodstains more effectively due to their high absorbency. In contrast, synthetic fabrics like polyester showed faster reduction in stain intensity. The green and blue values increased slightly after washing, reflecting the fading of the stain and exposure of the fabric's original colour. The study demonstrates that RGB analysis can detect subtle changes in bloodstains that may not be visible to the naked eye. This makes it a valuable tool in forensic investigations.

VI. APPLICATIONS OF RGB ANALYSIS IN FORENSIC SCIENCE

RGB analysis has emerged as a powerful tool in modern forensic science due to its non-destructive and quantitative nature. One major application is the detection of latent bloodstains. Even when stains are invisible, RGB analysis can identify subtle colour variations. It is also used in bloodstain age estimation by analysing colour changes over time. This helps establish timelines in criminal investigations.

RGB analysis can assist in differentiating between human blood and other substances, reducing false positives. The technique is cost-effective and accessible, as it can be performed using smartphones and basic software. Furthermore, it supports digital documentation of evidence, ensuring accurate record-keeping and analysis.

VII. CHALLENGES AND LIMITATIONS

Despite its advantages, RGB analysis has certain limitations. Lighting conditions can significantly affect image quality and colour accuracy. Variations in illumination may lead to inconsistent results. Fabric colour and texture can also influence RGB values, making analysis more complex. Environmental factors such as temperature and humidity may affect bloodstain appearance. Another limitation is the lack of standardization in image analysis procedures, which can affect reproducibility. Advanced techniques such as hyperspectral imaging may provide more accurate results but require specialized equipment.

VIII. FUTURE SCOPE

Future research can focus on integrating RGB analysis with advanced technologies such as artificial intelligence and machine learning. Automated systems can be developed to analyse bloodstains more efficiently and accurately. Combining RGB analysis with other techniques like hyperspectral imaging can enhance detection capabilities.

Further studies can explore the effects of different environmental conditions on bloodstain persistence. The development of standardized protocols will improve the reliability of RGB analysis in forensic investigations.

IX. CONCLUSION

This study highlights the importance of RGB image analysis in forensic science, particularly in the detection and analysis of bloodstains on fabrics. The findings demonstrate that bloodstains persist even after repeated washing, although their visibility decreases over time. The variation in stain retention across different fabrics emphasizes the role of material properties in forensic analysis. Natural fabrics tend to retain stains more effectively, while synthetic fabrics show faster fading.

RGB analysis provides a non-destructive, cost-effective, and quantitative method for examining bloodstains. It allows forensic investigators to detect hidden or partially removed stains, improving the accuracy of crime scene reconstruction. Despite certain limitations, the technique holds significant potential for future applications. With advancements in digital imaging and artificial intelligence, RGB analysis can become an integral part of forensic investigations.

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