Spectral analysis of blood stains at the crime scene

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11 - SUMMARY

Blood stains are an important source of information in criminal investigations, as blood stain patterns can inform investigators about the activities causing the stains, and subsequent DNA-analysis can identify or exclude possible suspects. In this thesis, we demonstrated several spectroscopic techniques for the detection, identification and age estimation of blood stains, as outlined in **Chapter 1**. The introduction emphasizes the need for innovative techniques which aid crime scene investigation. Because existing spectroscopic techniques are rapid, portable, and non-destructive, the described techniques are highly suitable for crime scene analysis.

An interesting technique for the non-destructive analysis of forensic traces is hyperspectral imaging. In **Chapter 2**, we review the application of hyperspectral imaging for the visualization and chemical analysis of forensic traces and describe its advantages and main challenges. Because hyperspectral imaging integrates conventional imaging and spectroscopy, both spatial and spectral information are obtained simultaneously, enabling investigators to analyze the chemical composition of traces and visualize their spatial distribution at the same time.

Both probe based spectroscopy and hyperspectral imaging are introduced as an indicative test for the identification of blood stains in **Chapter 3**. We propose a light-transport model to indicate the presence of the haemoglobin oxidation products oxyhaemoglobin (HbO_2), methaemoglobin (MetHb), and hemichrome (HC) from reflectance spectra of blood stains, enabling investigators to distinguish blood from other samples. The sensitivity and specificity of the technique are investigated, and the practical applicability is demonstrated in forensic casework.

Apart from the presence of haemoglobin oxidation products, the proposed light-transport model can be used to calculate the relative concentrations of HbO_2, MetHb and HC, which in turn can be used to estimate the age of a blood stain. In **Chapter 4** we successfully estimate the age of different blood stain patterns on white cotton backgrounds at a simulated crime scene using hyperspectral imaging. **Chapter 5** describes an adapted light-

transport model to correct for light absorptions of coloured backgrounds. Additionally, we describe a statistical approach to calculate an age interval for a questioned blood stain. The applicability of the new technique for blood stain age estimation in forensic casework and its possible value for criminal investigations is demonstrated in a case example. In the described homicide investigation, the results led to a more complete reconstruction of the timeline of events.

Chapter 6 covers the detection of latent blood stains on black backgrounds using visible hyperspectral imaging. At a crime scene, some blood stains may be invisible to the naked eye. Only after a stain is detected, it can be analysed further to be used as evidence in court, motivating the need for technology highlighting the contrast between a stain and its background. This chapter shows that blood stains can be distinguished from black fabrics based on the different absorption properties in the visible wavelength range.

In **Chapter 7** we analyse blood stains on black and coloured backgrounds using near infrared (NIR) spectroscopy. On these backgrounds, we successfully identify blood stains using correlation analysis and estimated their age using partial least squares regression analysis. Compared to visible spectroscopy, NIR spectroscopy provides more information about the chemical structure of samples, which is interesting for many forensic applications.

A final wavelength range explored in this thesis is the mid infrared or thermal wavelength range. All objects radiate infrared energy, invisible to the human eye, which can be converted into visible images by mid infrared cameras, thereby visualizing differences in temperature and/or emissivity of objects. **Chapter 8** provides an overview of the principles and instrumentation involved in mid infrared imaging. Difficulties concerning image interpretation are addressed. Reported forensic applications are reviewed and supported by practical illustrations, among which the detection of latent blood stains.

To conclude, all topics described above are discussed from a forensic practical point of view in **Chapter 9**. Emphasis is laid on further steps needed for the actual implementation of the described innovative techniques in standard forensic practice.