Toward a Spectroscopy-based Approach for Estimating Time Elapsed since Bloodstains Deposition – Development of a Novel Framework for Blood Evidence Evaluation

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A batch of evidence that has gained prominence in courtrooms are bloodstains, often the main driving force behind an investigation process. Unfortunately, in the era of DNA testing, it is frequently overlooked that verifying who was the "source" of the trace is not always the critical issue. It is prevalent among suspects not to question the identification of his/her blood but rather the time at which it was deposited at the crime scene. Thus, to increase the evidential value of the trace in question, it is often necessary to demonstrate a unity of time and place, proving that the person of interest was on the crime scene within a given time interval. This can be done by providing the final piece of the forensic puzzle – information about bloodstains' age.

The attempt to estimate the time elapsed since trace deposition is possible due to aging processes, which lead to alterations in physicochemical properties of the examined bloodstain. Surprisingly, despite the nearly century-old research efforts, a reliable method for estimating bloodstains' age is still missing. Having looked into previous examples of dating studies, it can be concluded that it is the wrong approach for data analysis, which should be blamed for the delayed exploitation of already developed methods in forensic practice. It seems that there is a significant discussion, but any proposed way forward leads to the same intractable crossroads. According to the universally adopted strategy, the majority of proposed dating techniques have been guided by a simple principle – they have sought the dependency between some dynamic properties of degrading blood and time, usually through the employment of regression analysis. The aging process, however, is not only a matter of time. No two crime scenes are ever precisely the same. Neither are the degradation pathways of blood deposits; hence, using dating models trained on the very limited datasets might lead to misestimations of bloodstains' age, depriving these conventional methods of entire practical value.

The present dissertation takes a few steps back to investigate the dating problem from an entirely different perspective and, eventually, proposes the novel framework for estimating time elapsed since bloodstains deposition. It is hypothesized that impediments resulting from variability of aging kinetics can be addressed by substituting a case-suited comparison problem for the conventional dating approach. The critical aspect of this concept is the likelihood ratio-based assessment of the (dis)similarity between the stage of evidence decomposition and sets of reference materials obtained through supervised aging. This means that every dating procedure would be constructed on a case-by-case basis, each time tailored to fit the examined traces. In such a way, the influence of external factors (donor characteristics, environmental conditions, nature of the substrate) on the analysis's validity should be considerably reduced.

Establishing such a procedure was considered a dual problem that required addressing two distinct issues. In the first part of the research, an analytical method for characterizing the state of bloodstains degradation was developed. Given the characteristics of the examined trace, the choice of Raman spectroscopy seemed a logical decision. And, indeed, the obtained results proved the effectiveness of Raman spectroscopy as a method capable of delivering information inherent to chemical changes accompanying the degradation process of heme-containing proteins. After establishing a Raman-based strategy for non-invasive and representative probing of the chemical alterations of aging bloodstains, the research entered the next phase. The second part of the study focused on designing the likelihood ratio (LR) models for solving the so-called comparison problem between the questioned bloodstain and the reference material(s) created in a supervised manner. Results of models' validation provided preliminary confirmation of the effectiveness of the proposed dating approach. Best performing LR models were deemed satisfactory (with false positive and false negative rates oscillating around 20% and 10%, respectively) but provided that samples used for training and validating models were characterized by similar aging kinetics. This conclusion, however, should not come as a surprise since providing reference materials as similar as possible to the evidence deposited during the offense is, in fact, a fundamental requirement of the proposed methodology.