D42 Exsanguinated Blood Volume Estimation Using Fractal Analysis of Digital Images

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The goals of this presentation are to introduce attendees to chaos theory and fractal geometry and to demonstrate how fractal analysis may be applied to the characterization of non-linear, morphometrically complex, bloodstain patterns, and ultimately lead to a scientifically reproducible means of estimating exsanguinated blood volume.

This presentation will impact the forensic science community by providing a novel approach to estimating single-event exsanguinated blood volume from blood spatter evidence at crime scenes. This method results in the deconstruction of bloodstain patterns into mathematical parameters thereby removing the subjective element inherent in previous studies. This analytical approach represents a shift from a formerly subjective field towards a more objective analytical technique that can withstand scientific and legal scrutiny.

Although the field of bloodstain pattern analysis has evolved to combine a unique set of well-defined and established scientific principles, drawing on many disciplines to characterize and interpret stain patterns, there is currently no scientifically accepted, or court qualified method of quantifying original bloodstain volume. This information may be vital in cases where a large volume of blood must be correlated to determining post injury survival time, the location of severe or lethal injuries, and the probability of death when no body is found.

The present study combines a quantitative analytical approach with an area previously dominated by subjective qualitative observations and allows the modeling of natural systems such as blood spatter. This research has lead to the development of a novel fractal approach to the estimation of bloodstain volume, which deviates from the classical direct volumetric methods previously proposed by Lee (1986). Variability of the appearance of different bloodstains can be simplified and quantified into a single numerical value that defines its shape complexity, namely its fractal dimension, and are ideally suited for computer analysis, hence, removing inherent observer bias.

The central hypothesis of this analytical technique is that digital images of bloodstain patterns are quantifiable using fractal geometry, hence, each volume may be characterized by a unique Hausdorff fractal dimension. This allows the analyst to provide an estimated volume with a statistically valid methodology in order to conform to *Daubert* Standards.

Binary photographs of passive bloodstains of known volume were subjected to computer analysis using FracLac V2.0 for ImageJ. Through application of the box-counting method, the Hausdorff fractal dimension of each replicate volume was extracted from a scaling plot of these data. Generated fractals were utilized to create scatter plots yielding logarithmic regression predictive equations for blood. Fractal curves, of known and accepted Hausdroff dimension were used to calibrate the system. The validity of the proposed methodology was assessed during a blind trial evaluation.

The results of this study indicate that chaos theory and fractal geometry may be applied in a systematic method to assist in quantitative analysis and modeling of passive bloodstains by a unique geometric Hausdorff fractal dimension through application of the box-count method. A power law relationship is observed when the box size is plotted against the number of grid boxes that contain pixels in a box- counting scan. A scaling plot was subsequently generated by performing a logarithmic manipulation of these data and the fractal dimension was extracted from the slope of the linear portion of this plot. This procedure was repeated for each replicated volume.

Passive blood stain patterns are characterized by a fractal dimension duality due to the underlying mechanisms that influence the resulting primary and secondary spatter, that in combination form the overall pattern. This study used a single line of best fit for the extraction of the fractal dimension from the generated scaling plot.

The regression yielded a logarithmic function that was predicted from the power law. The fractal dimension approached 2, asymptotically. Mathematical theory suggests that as the fractal dimension of a 2-dimensional natural object increases, it will do so as a limit, approaching, but never reaching, 2.0. At this point the pattern is no longer considered fractal and becomes Euclidean.

This study provides the basis for the estimation of blood volume from the fractal analysis of digital images; forging the way for more detailed investigations, while highlighting areas that demonstrate the potential for future research.

Bloodstain Pattern Analysis, Fractal Analysis, Volume Estimation