Toward Accurate Methods for Forensic Bloodstain Pattern Analysis

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Abstract: At present, bloodstain pattern analysis (BPA) is largely an empirical, qualitative sub-discipline of forensic science. Forensic BPA specialists analyze bloodstains found at crime scenes and attempt to infer the location of the blood-letting impact (or impacts) that caused to the bloodstains. Traditional BPA methods for reconstructing crime scenes (notably stringing) ignore the effects of gravity and aerodynamic drag on trajectories of blood droplets in flight. Such assumptions may produce acceptable qualitative predictions under certain conditions (e.g., when analyzing bloodstains caused by droplets moving at high speeds due to discharge of a firearm). However, in many circumstances, back-tracking blood droplets along straight lines from bloodstains to a static impact location is misleading (e.g., when bloodstains are caused by assault with a blunt instrument or an edged weapon).

We have developed a sound physically accurate forward differential equation model for blood droplet flight (i.e., one incorporating gravity and air resistance) leading to bloodstain pattern formation. We have incorporated this forward model into an optimization problem to back-track elliptical bloodstains along curved trajectories determined by ODEs rather than straight lines determined by geometric arguments. We present some preliminary results to illustrate our methods for crime-scene reconstruction. Our ultimate aim is to develop software tools for quantitative analysis to support forensic BPA analysts.

Our forward model has been developed using pre-recorded videos of experiments simulating blood-letting events. The simulations consist of fake blood encased in ballistic gel being splattered by projectiles. The resulting blood flight trajectories are recorded by a stereo pair of high-speed cameras and the bloodstains are photographed to provide a collection of video and static image data sets to validate our inversion framework. We employ a sophisticated algorithm incorporating background removal, segmentation, 2D motion tracking and 3D reconstruction to extract meaningful flight trajectories from the video data.

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