D41 Body-Mounted Camera Motion Analysis—Accuracy and Validation of 3D Camera Match Solutions

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Learning Overview: After attending this presentation, attendees will have an understanding of dynamic camera analysis, applying photogrammetric techniques to validate results, and the various challenges faced by investigators, engineers, and scientists in solving for evidence in a moving camera system.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by establishing forensically sound methodology in the photogrammetric analysis of video evidence from body-mounted camera systems, using widely available tools from both the accident reconstruction and motion picture industries.

The analysis of video evidence captured by a moving camera system is one of the most difficult tasks faced by reconstruction professionals. While static photogrammetry techniques can be utilized with individual video frames, the vast number of image frames in a single video file make this method both time- and cost prohibitive. High frame rates (images per second), camera lens distortion, low-light scenarios, and image compression artifacts further complicate solutions using traditional photogrammetry. The motion picture industry heavily relies on the ability to solve for moving cameras in video compositing—that is, combining live video footage with rendered 3D objects. In movie production, the solution of moving camera footage is referred to as match-moving or camera-tracking. In this study, camera-tracking techniques are employed to solve for the motion of two of the most common sources of video evidence: Axon® body cameras (commonly worn by peace officers), and GoPro® action cameras (commonly worn by civilians and athletes). This report presents a study validating match-moving techniques used to solve for dynamic camera positions and objects within video frames.

In the first phase of a validation study, body-mounted action cameras are used in an environment optimized for photogrammetry: an indoor laboratory with uniform overhead lighting, a checkerboard floor texture, and a pre-defined motion capture area. The human test subject is equipped with a body-mounted camera and a biomechanical 3D motion capture suit that records body segment locations, speeds, rotations, and accelerations. The human motion is also recorded by static overhead video cameras. Key camera locations in the dynamic sequence are solved using static terrestrial photogrammetry. The statically solved camera positions are then compared with the solutions obtained using match-moving/3D camera tracking and the biomechanical motion capture suit.

After validating the optimized camera solutions using match-moving software, the study is extended into a non-optimized environment. The outdoor scene selected is a typical mixed-use industrial area, with large variations in sunlight/contrast, and very few idealized tracking references. The human test subject is instrumented with the motion-capture suit and a body-mounted camera and put through a series of motions, including walking, running, backing away from another human, and climbing a fence. The camera motion is solved using match-moving/3D camera tracking, and the solution is compared with the validated motion capture data set.

The results of this study show that 3D camera tracking or match-moving software can be used accurately to automate body-mounted camera motion solutions. Recommended guidelines include specific (key frame) static photogrammetry solutions to verify important locations in video footage. Pitfalls and other potential issues with frame rate, lens distortion, rolling shutter effects, and artifacts are discussed in detail. The presented methodology can be extended to both the criminal (officer-involved incidents) and civil (collision analysis) domains of reconstruction.

Photogrammetry, Video, Analysis

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