LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

UCRL-CONF-220395

Optical bullet-tracking algorithms for weapon localization in urban environments

R. S. Roberts, E. F. Breitfeller

April 5, 2006

National Military Sensing Symposium
Orlando, FL, United States
November 14, 2006 through November 17, 2006

Optical bullet-tracking algorithms for weapon localization in urban environments

Randy S. Roberts and Eric F. Breitfeller
{roberts38, breitfeller1}@llnl.gov
Lawrence Livermore National Laboratory

Localization of the sources of small-arms fire, mortars, and rocket propelled grenades is an important problem in urban combat. Weapons of this type produce characteristic signatures, such as muzzle flashes, that are visible in the infrared. Indeed, several systems have been developed that exploit the infrared signature of muzzle flash to locate the positions of shooters. However, systems based on muzzle flash alone can have difficulty localizing weapons if the muzzle flash is obscured or suppressed. Moreover, optical clutter can be problematic to systems that rely on muzzle flash alone.

Lawrence Livermore National Laboratory (LLNL) has developed a projectile tracking system that detects and localizes sources of small-arms fire, mortars and similar weapons using the thermal signature of the projectile rather than a muzzle flash. The thermal signature of a projectile, caused by friction as the projectile travels along its trajectory, cannot be concealed and is easily discriminated from optical clutter. The LLNL system was recently demonstrated at the MOUT facility of the Aberdeen Test Center [1]. In the live-fire demonstration, shooters armed with a variety of small-arms, including M-16s, AK-47s, handguns, mortars and rockets, were arranged at several positions in around the facility. Experiments ranged from a single-weapon firing a single-shot to simultaneous fire of all weapons on full automatic. The LLNL projectile tracking system was demonstrated to localize multiple shooters at ranges up to 400m, far greater than previous demonstrations. Furthermore, the system was shown to be immune to optical clutter that is typical in urban combat.

This paper describes the image processing and localization algorithms designed to exploit the thermal signature of projectiles for shooter localization. The paper begins with a description of the image processing that extracts projectile information from a sequence of infrared images. Key to the processing is an adaptive spatio-temporal filter developed to suppress scene clutter. The filtered image sequence is further processed to produce a set of parameterized regions, which are classified using several discriminate functions. Regions that are classified as projectiles are passed to a data association algorithm that matches features from these regions with existing tracks, or initializes new tracks as needed. A Kalman filter is used to smooth and extrapolate existing tracks. Shooter locations are determined by solving a combinatorial least-squares solution for all bullet tracks. It also provides an error ellipse for each shooter, quantifying the uncertainty of shooter location. The paper concludes with examples from the live-fire exercise at the Aberdeen Test Center.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

[1] Stephen Snarski, et. al., “Autonomous UAV-based mapping of large-scale urban firefights,” to appear in Proceedings of the SPIE Vol. 6209 *Airborne Intelligence, Surveillance, Reconnaissance (ISR) Systems and Applications, III,* SPIE Defense and Security Symposium, 17-21 April 2006.