Shooter Localization in Urban Terrain

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Detecting and accurately locating snipers has been an elusive goal of the armed forces and law enforcement agencies for a long time. Existing countersniper systems use acoustic, visual, infrared, or electromagnetic signals related to gunfire to determine a shooter's bearing or exact location.[1] The main limiting factor in these systems is a line-of-sight requirement.

Most successful sniper-detecting systems are based on acoustic measurements. As Figure 1 shows, the observable sound originates from either the muzzle blast or the acoustic shock wave that a supersonic projectile produces.

PINPTR ACOUSTIC SYSTEM

The performance in most current acoustic systems significantly degrades when used in urban terrain because multipath effects typically corrupt the available sensor readings. However, we have developed an acoustic system that works well even in complex urban environments (www.isis.vanderbilt.edu/projects/nest/applications.html).

Funded through the Network Embedded Systems Technology program of the US Defense Advanced Research Projects Agency's Information Exploitation Office, the PinPtr system uses a wireless network of many low-cost sensors to determine both a shooter's location and the bullet's trajectory by measuring both the muzzle blast and the shock wave.[2]

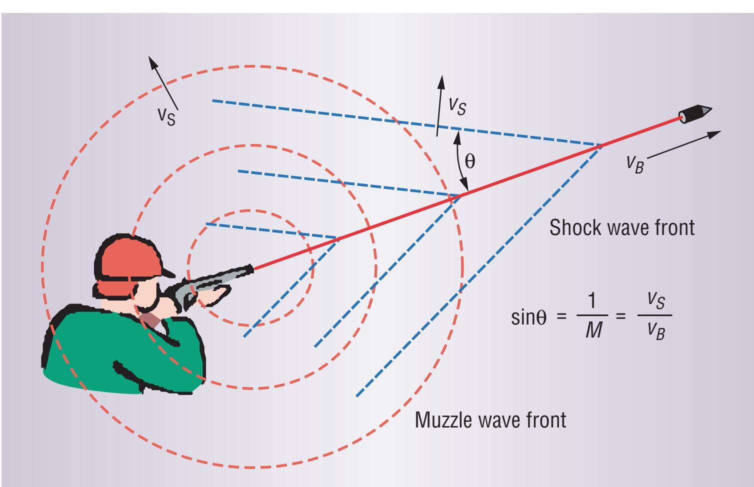

Figure 1. Acoustic events generated by a shot. The muzzle blast produces a spherical wave front that travels at the speed of sound (v_s) from the muzzle. The supersonic projectile generates a shock wave in every point of the trajectory, producing a cone-shaped wave front (assuming the speed of the projectile is constant v_B). The projectile's Mach number M determines the angle of the shockwave cone.

Similar to traditional systems, PinPtr estimates the source location based on the measured time of arrival of acoustic events, known sensor locations, and the speed of sound. However, traditional systems use time-difference-of-arrival equations, making them susceptible to multipath effects.

The PinPtr sensor-fusion algorithm, which runs on a base station, performs a search on a hypersurface defined by a consistency function. This function provides the number of sensor measurements that are consistent with hypothetical shooter positions and shot times. The algorithm automatically classifies measurements and eliminates those that result from multipath effects or are otherwise erroneous. A fast search algorithm finds the global maximum of the surface,[2] which corresponds to the shooter position.

PinPtr can use hundreds of sensors. Users can either deploy the sensors manually, placing them in predetermined locations, or drop them in a random formation by some other means. After deployment, the sensors automatically establish an ad hoc communication network, perform self-localization, and establish a common time base. The system is then ready to use.

When the system detects an event, it measures the time of arrival and uses a specially tailored data aggregation and routing service to propagate the information through the network to the base station.

PROTOTYPE IMPLEMENTATION

We built a PinPtr prototype on top of the University of California, Berkeley's MICA2 mote platform running TinyOS.[3]

While it provides an excellent low-cost hardware and software platform for sensor network applications, severe resource constraints prohibit the implementation of muzzle blast and shockwave detection on the mote itself. Therefore, we developed a custom acoustic sensor daughter card to execute the signal-detection and time-stamping algorithms on an on-board field-programmable gate array.

The mote itself runs the operating system; middleware services such as time synchronization, data

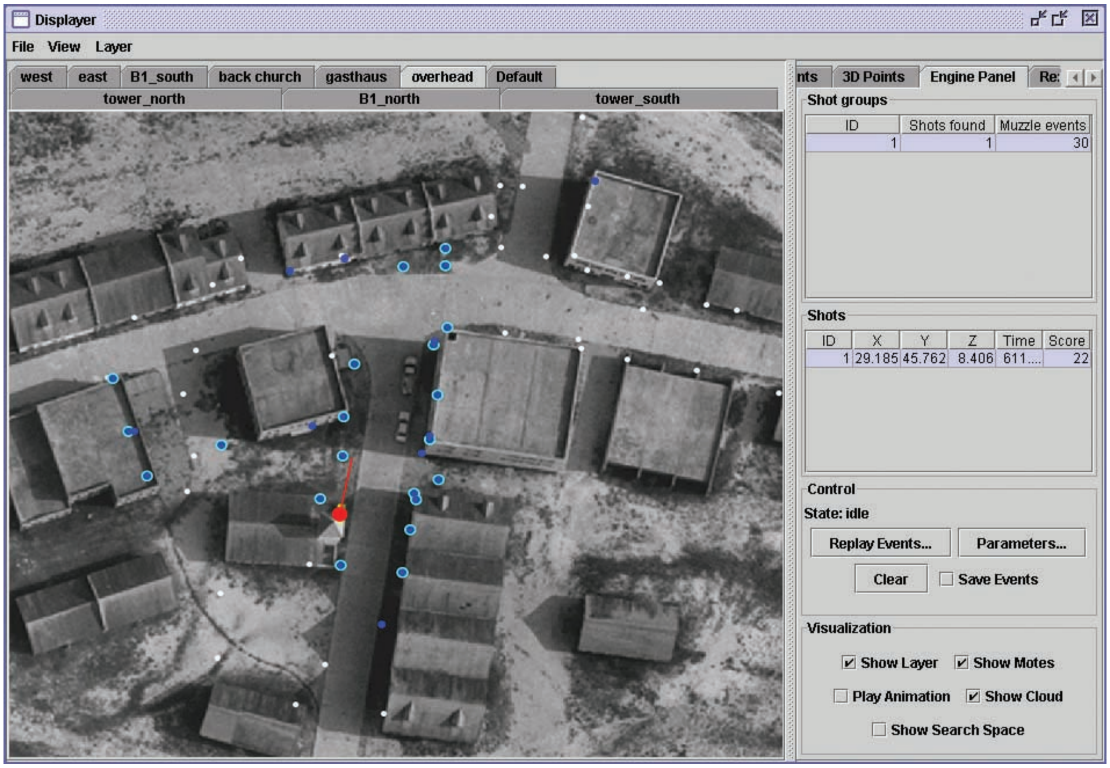

Figure 2. PinPtr interface. In an overhead shot of the test area, the red dot shows the estimated shooter position, and the red line indicates the direction of the shot. The coordinates, including the elevation (8.4 m), are displayed on the right-hand side. Colored circles and dots show the sensor locations: white—no detection; blue—detection; cyan—line-of-sight detection.

aggregation, and message routing; and application-specific routines.

We demonstrated and evaluated the prototype in a US Army test facility that offered a realistic urban environment. Figure 2 shows the 100 × 100-meter test area.

We deployed 60 sensors for the test, and the system accuracy was approximately 1 meter on average in three dimensions. This meant that PinPtr could determine the exact window from which a particular shot was fired. The system latency was less than 2 seconds.[2]

The PinPtr system and test show the value of wireless networks in bringing highly redundant sensing and distributed processing to solve a difficult problem. ■

References

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