Poster: Acoustic Sensing for Detecting Projectile Attacks on Small Drones

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ABSTRACT

Autonomous drones have become increasingly popular in applications such as trusted delivery and law enforcement. This makes them vulnerable to midair attacks for profit and vandalism. While modern aircrafts can detect and defend against projectile attacks using radar and antenna arrays, small drones cannot leverage such techniques. The primary challenges are their (a) small form factor and weight carrying capacity, (b) limited computational power, and (c) limited power source. We envision to develop an ecosystem of lightweight and low-power defense modules for small drones. This project explores the viability of this vision. As proof of concept, we develop a single microphone-based acoustic sensing mechanism capable of identifying if an approaching projectile is about to hit the drone. Our system, called DopplerDodge, transmits acoustic signals and leverages doppler frequency shifts in the reflected signal to predict the projectile's intention.

The core intuition of DopplerDodge [1] is that the Doppler frequency shift [2] observed by a microphone depends on the object's direction of motion. Equation 1 shows that the magnitude of doppler shift Δf depends on the velocity of sound v_{sound}, velocity of reflector object v_r and the radial angle θ made by the object with the straight line joining with the microphone.

$$\Delta f = f_s \frac{2 v_r cos(\theta)}{v_{sound}} \quad (1)$$

Figure 1 illustrates that the radial angle θ remains zero when the object is moving along the straight line toward the microphone, while for any other case this angle increases exponentially. This results in a constant doppler frequency shift over time when the object is going to collide with the drone. We call this as a *Hit* case. On the other hand, in a *Miss* case, the doppler frequency decreases exponentially. We develop a system that observes this trend in doppler shift and outputs a one-bit information about the intention of the projectile as *Hit* or *Miss*. Figure 2 shows the trend in the Doppler shift for a *Hit* and a *Miss* case when a toy bullet was shot toward the sensor. DopplerDodge is built on this core intuition to develop a low-latency sensing system that can detect if a projectile is going to hit the drone or not. We develop a time-domain technique to estimate the change in Doppler frequency over time. An elaborate description of the technique is included in [1].

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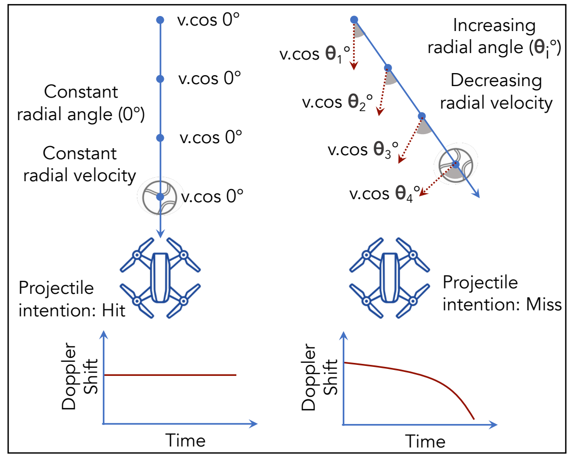

Figure 1: The different trends in the radial velocities and the Doppler frequencies when the projectile hits and misses the target.

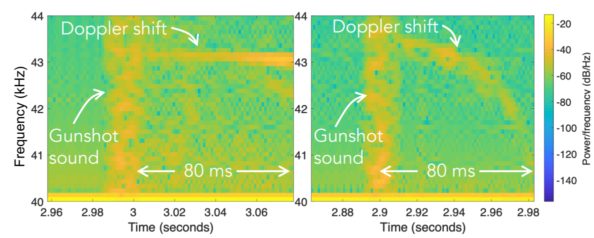

Figure 2: Spectrograms showing the doppler frequencies for two cases when a toy bullet is shot. In the first case, the bullet hits the sensor, and in the second case, it misses the sensor by twenty centimeters.

CCS CONCEPTS

• **Computer systems organization → Embedded and cyber-physical systems**; **Sensors and actuators**;

KEYWORDS

Low-power acoustic sensing; Projectile intention detection

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