Micropower Impulse Radar (MIR)

Ohio State ♦ UT Austin ♦ Michigan State ♦ Iowa ♦ Kent State

Suitability for Sensor Networks

- Low power: < 50mW power consumption
- Low cost: < $50 in volume
- Omni-directional FOV: allows randomized deployment
- Line-of-sight not required: works through rocks, trees, etc.
- Provides simple digital and richer analog output signals

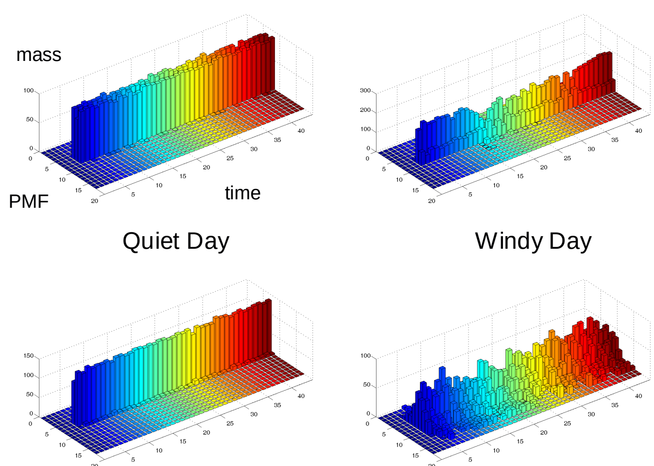
Theory of Operation

- Transmit a very short ultra-wideband (UWB) pulsed signal
- Ignore reflections due to the surrounding environment
- Signal reflected from a moving target experiences a Doppler shift (frequency) related to the target velocity
- Output signal amplitude is proportional to reflected energy
- Output signal instantaneous frequency is proportional to target radial velocity

Motion Detection

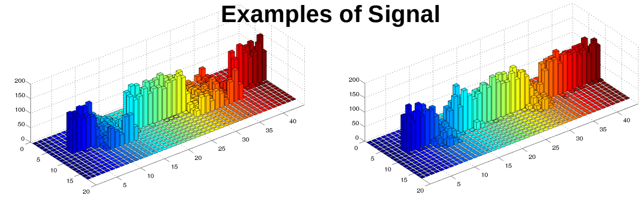
- Problem: Determine the presence of an *unknown* or *loosely parameterized* signal in the presence of *unknown noise* using constrained computational resources
- Assume: Signal PDF ≠ Noise PDF
- Assume: $\sigma_{Signal}^2 > \sigma_{Noise}^2$ over interval of interest
- Approach: Build PMF (discrete PDF) by sampling over a moving interval; compute an estimate of the variance; compare to a moving variance threshold based on a CFAR

Examples of Noise



Quiet Day · Windy Day · Quiet Night · Rainy Night

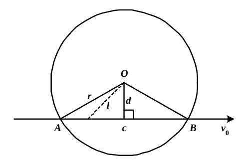
Examples of Signal



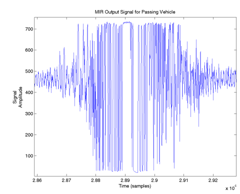
Walking · Running

Velocity Estimation

- Problem: Determine the target velocity (radial component)
- Output crosses "zero" for every $\lambda/2$ units of distance traveled
- Radial velocity $v_r = \lambda/2t_z$, where t_z is the time between two successive zero crossings and λ is 6.25 cm
- As target passes MIR along a secant *AB*, instantaneous output frequency goes from high (entering detection circle at *A*) to zero (closest point of approach or CPA at *c*) to high again (exiting detection circle at *B*)



Target Trajectory



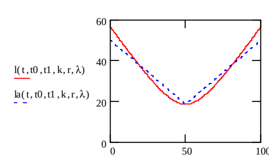
Corresponding Output

Range Finding

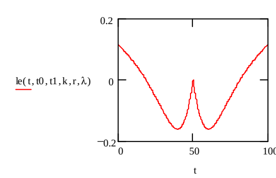
- Problem: MIR sensor does not provide target ranging
- Approach: Note detection beginning and ending times; count zero crossings during signal presence; estimate range using the following approximate estimation:

$$range\ (t, t_0, t_1, k, r, \lambda) \approx k\lambda/4[|1 - 2t/(t_1 - t_0)| - 1] + r$$

- Where $t : t_0 \le t \le t_1$; k is the number of zero crossings; r is the detection radius; λ is the wavelength (12.5 cm)



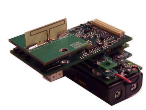
Ground Truth (red)
Estimation (blue)



Estimation Error

Conclusions and Future Plans

- Demonstrated integration with Mica Mote platform and detection/estimation algorithms



Self-righting Enclosure

- Target Localization (triangulation) using three or more MIR sensors
- Sensor Self-Localization (variation on mobile beacon-based) sensors "learn" relative positions using target ranging