Detection and Identification of Remotely Piloted Aircraft Systems Using Weather Radar

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Motivation – UAV misuse

- rogue drones in airport vicinity
- espionage and data hacking
- fly contraband into prisons
- terrorist drone threat

Laws can be enforced only if the threat is detected!
Approach – micro-Doppler analysis

Mechanical vibrations or rotations of structures on a target may introduce frequency modulation on the radar return known as the micro-Doppler (m-D) phenomenon.

Relevant features for drone detection - theory

- **Spectrum width**
  - several meters per second for birds
  - much wider for drones
  - high sampling rates are necessary to avoid micro-Doppler signature aliasing

- **Spectrogram symmetry**
  - symmetric for drones
  - asymmetric for birds

- **Spectrogram periodicity**
  - determined by rotor rotation rate or wing beat
  - higher for drones
  - high sampling rates are necessary

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Experiment setup

- beam azimuthal resolution at the drone location \( \sim 8 \) meters
- range gate resolution – 24 meters
- drone to radar distance \( \sim 400 \) meters

- drone (hexacopter) hovered or flew in circles within a single radar range gate
- high-power, dual-polarized radar with a fixed antenna (10 degree elevation tilt) and PRF = 1kHz
Drone observations

- High standard deviation in differential channel power
- Correlation coefficient larger than 0.8 when drone is within a beam
- No significant difference in spectrograms for H- and V-polarizations
- Multiple peaks in spectrogram due to low sampling frequency and multiple rotors
Drone statistics

- Statistics represent 80 seconds of a hovering drone dataset.
- On average 3+ peaks in spectrum are detected.
- Main peak significantly stronger when compared with secondary spectrum peaks.
Bird observations

- even number of peaks in spectrogram
- comparable power in peaks
- spectrum width of multiple birds can be comparable to drone
Birds statistics

- Statistics represent 12 different bird(s) observation (~50 seconds)
- On average 2 comparable peaks in spectrum are detected
- Positive Zdr with narrower distribution when compared to drone
Support vector machine classifier (drone vs. bird)

- commonly used for a binary classification
- attempts to find a hyperplane that divides the two classes with the largest margin in a high-dimensional feature space
- uses a subset of training points in the decision function (called support vectors) and is memory efficient
Classifier performance

- up to 80 seconds of hovering drone observations and 50 seconds of bird observations used to train the SVM classifier using the means and standard deviations of the 4 features – number of spectral peaks, standard deviation of first two peaks, correlation coefficient, and differential phase

- 80 seconds dataset representing maneuvering drone was used for classifier evaluation

- visible trend in correct classification as the size of the training set is increased
Conclusions

- Weather radar can detect and identify a remotely piloted aircraft system, but high sampling rates are recommended to avoid micro-Doppler signature aliasing.

- Micro-Doppler signature is the most distinctive feature to distinguish drones from birds.

- Machine learning can be used to distinguish birds from drones, but more data (of drones and birds) is needed to improve classifier performance.

- Additional features and machine learning algorithms need to be evaluated.
Future work

- UMass received an NSF grant to demonstrate the drone detection and tracking capabilities of its weather radars

- experiments scheduled for Fall’17 using a phase-spin weather radar

- this radar scans electronically in the elevation plane and move mechanically in the azimuth

- capable of scanning the entire sky (volume scans)

    drone signature detected at 1180m using a solid-state low-power radar
Thank You!

Questions?