Matthan: Drone Presence Detection by Identifying Physical Signatures in the Drone’s RF Communication

Phuc Nguyen, Hoang Truong, Mahesh Ravindranathan, Anh Nguyen, Richard Han, Tam Vu
Drone accidents have increased
Drone accidents have increased

Drone Hits an Airplane

Drone Crashes Through Window

Drone Hits Man's Head
Ways to take down illegal drones

Assume drone presence is known a priori
Existing acoustic-based detection

Super-quiet drones take inspiration from silent owls

By ROBERT BECKHUSEN
Friday 20 July 2012

For spy tools, drones are pretty easy to spot. And hear, because they’re as loud as a gut-busting rock concert. But now the intelligence community’s research division, Iarpa, plans to start designing a silent drone inspired by quiet, creeping, flying owls.

Tien Pham et. al., U.S. Army Research Laboratory
Existing video-based detection

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<table>
<thead>
<tr>
<th>mUAVs</th>
<th>Aircrafts</th>
</tr>
</thead>
</table>

Disadvantages:
1. Short range (max. 50m)
2. Require Line of Sight
3. Light Condition Dependent
4. Hard to differentiate between Drone and Birds

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Drones Can be Rendered Invisible With New Teflon Cloaking Technology

By reflecting their surroundings, UAVs can disappear.

Yasmin Tayag | September 8, 2015

Tamas Zsedrovits et. al., 2011, 2012
Existing active radar-based detection

This technique creates much interference to the environment and expensive
Can we detect the drone using a Wi-Fi access point?

- Cost-effective
- Ubiquitous
- Internet connected
Matthan Drone Detection System

Explore physical signatures in the received RF signal:

• **Body Shifting** (caused by Control Loop Mechanism)
• **Body Vibration** (caused by Propellers Motion)
Drone movements can happen with unpredicted patterns. Wi-Fi embedded in mobile devices, Wi-Fi hotspot inside moving vehicles, and drone movements can happen with unpredictable patterns.
Body Shifting Observation

Corresponding movement waveform:

Idea: The body movement of the drone can be detected by a wavelet transform analysis.
Body Shifting Validation

- Drone is attached TX antenna and IMU
- Observe the signal from IMU and RX when the drone is flying (indoor)

The drone movements modulate the wireless signal that sent from the transmitter attached to it.
Validating the use of Wavelet Transform to detect body shifting signature.

- Take off
- Body shifting signature
- EMF Noise
- Landing

Time (s) | Scale
--- | ---
0 | 0
5 | 0
10 | 0
15 | 0
20 | 0
25 | 0
30 | 0
35 | 0
40 | 0
Idea: The body vibration of the drone can be detected by a Fast Fourier Transform analysis.
Body Vibration Validation

IMU
Microcontroller
Bluetooth Module

IMU data
Wireless data
Matthan’s Overview

1. Moving Object Detection
2. Body Shifting Patterns
3. Coefficient Variances
4. Temporal Consistency
5. Event Singularity
6. Body Vibration

Wi-Fi samples collection → Pre-processing → STFT → Wavelet Transform

Evidence collection:
- Confirmed

Drone is detected
Evaluation

• Hardware
  • SDR USRP B200
  • 2.4GHz directional antenna
  • Carrier Sensing: Wi-Fi Analyzer app on Android

• Environment setup
  • Environments: Urban, Campus, Sub-urban
  • Distance: 10m → 600m
Detecting Different Drones

Distance = 50m
Detect Drones at Different Distances

Distance from 10m to 600m
Detecting Drones at Different Environments

Accuracy | Precision | Recall
---|---|---
Urban: 93.9 | 92.2 | 96
Campus: 92 | 88.7 | 96.3
Sub-urban: 96.7 | 95.9 | 97.3
## Drone Differentiation

<table>
<thead>
<tr>
<th>Drone</th>
<th>Bebop</th>
<th>DJI</th>
<th>Galileo</th>
<th>Dronium</th>
<th>Sky Viper</th>
<th>Swift Stream</th>
<th>AR Drone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration Freq.</td>
<td>60 Hz</td>
<td>100 Hz</td>
<td>140 Hz</td>
<td>35 Hz</td>
<td>50 Hz</td>
<td>20 Hz</td>
<td>70 Hz</td>
</tr>
</tbody>
</table>

### Vibration Frequency Comparison

- **Max**:
  - Bebop: 89.7%
  - DJI Phantom: 83.3%
  - Galileo: 15.4%
  - Dronium: 73.3%
  - Sky Viper: 13.7%
  - Swift Stream: 1.7%
  - AR Drone: 6.3%
  - Unclassified: 4.0%

- **Min**:
  - Bebop: 0.0%
  - DJI Phantom: 0.0%
  - Galileo: 0.0%
  - Dronium: 0.0%
  - Sky Viper: 0.0%
  - Swift Stream: 0.0%
  - AR Drone: 0.0%
  - Unclassified: 64.0%
Future Works

• Develop an automated channel sensing (similar to cognitive radio spectrum sensing)

• Integrate automated steering/ beamforming antenna

• Localize the position of the drone

• Detect multiple drones at the same time
Conclusions

• We introduce a system to detect the presence of the drones by identifying unique signatures:
  • drone’s body shifting and
  • drone’s body vibration

• The system obtained high performance
  • at different distances,
  • in different environments, and
  • with different types of drones.
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