Eye in the Sky: An Automated UAV System for Wildlife Tracking

Gabriel Vega
Michael Shafer, PhD
Carol Chambers, PhD

October 08, 2018
The Wildlife Society Conference 2018
Cleveland, OH
Outline– UAV-RT

• Current Issues with Wildlife Tracking
  – Addressing inefficiencies and risk

• Field UAV Design
  – Packable (protected when stored)
  – Simple fabrication and field repairable

• Radio Telemetry Development
  – UAV radio relay (400 ft pole for antenna)
  – Environment mapping, DOA, and estimated tag localization

• Technology Dissemination
  – Website development
    • System design (plans, tutorials)
    • Open source software and firmware

• Future Work
  – Automated localization/path planning implementation
  – Synthesis of data analysis (easy field use)
Outline—UAV-RT

• Current Issues with Wildlife Tracking
  – Addressing inefficiencies and risk

• Field UAV Design
  – Packable (protected when stored)
  – Simple fabrication and field repairable

• Radio Telemetry Development
  – UAV radio relay (400 ft pole for antenna)
  – Environment mapping, DOA, and estimated tag localization

• Technology Dissemination
  – Website development
    • System design (plans, tutorials)
    • Open source software and firmware

• Future Work
  – Automated localization/path planning implementation
  – Synthesis of data analysis (easy field use)
Current Issues

• Current search methods are inefficient
  – Limited access to rough terrain
  – Dangerous and costly manned aircraft searches
  – Timely cross-country hiking
• GPS tags present additional cost and weight
UAV-Radio Telemetry Research Program

- Collaboration: biologists, electrical & mechanical engineers
- Final system will integrate autonomous flight capability with onboard data processing
- Improved mobility and vantage point
Outline—UAV-RT

• Current Issues with Wildlife Tracking
  – Addressing inefficiencies and risk

• Field UAV Design
  – Packable (protected when stored)
  – Simple fabrication and field repairable

• Radio Telemetry Development
  – UAV radio relay (400 ft pole for antenna)
  – Environment mapping, DOA, and estimated tag localization

• Technology Dissemination
  – Website development
    • System design (plans, tutorials)
    • Open source software and firmware

• Future Work
  – Automated localization/path planning implementation
  – Synthesis of data analysis (easy field use)
Packable Design
Packable Design

- Carbon layers
- Aluminum standoff supports
- Structural supports
- GPS Module
- Flight Computer
- Detachable Arms
- Battery Layer
- Onboard Computer
- Payload Modules
Outline—UAV-RT

- **Current Issues with Wildlife Tracking**
  - Addressing inefficiencies and risk

- **Field UAV Design**
  - Packable (protected when stored)
  - Simple fabrication and field repairable

- **Radio Telemetry Development**
  - UAV radio relay (400 ft pole for antenna)
  - Environment mapping, DOA, and estimated tag localization

- **Technology Dissemination**
  - Website development
    - System design (plans, tutorials)
    - Open source software and firmware

- **Future Work**
  - Automated localization/path planning implementation
  - Synthesis of data analysis (easy field use)
System Overview

Radio Tag

UAV

Radio Telemetry Avionics

Flight Avionics

SDR

RC receiver

Ground Control Station

Wi-Fi Data Link

Vehicle Telemetry Radio

R/C Controller

Headphones

System Diagram:

- Radio Telemetry Avionics
- Flight Avionics
- SDR
- RC receiver
- Wi-Fi Data Link
- Vehicle Telemetry Radio
- R/C Controller
- Headphones
• GNU radio software used with Airspy (SDR front end)
• Software used to input and store incoming signal from beacon

Image credit: https://airspy.com/airspy-r2/
Ground Station
Lake Mormon Testing Site
Flight video – Search Method
DOA Estimation

Data processing stages:

- **Raw Data (grey)**
- **Data Filtered (yellow)**
- **Maximus determined (blue dot)**
- **Pulses Detected (blue dot)**
- **Matched to Vehicle Heading (blue)**
- **Bearing Estimation (blue arrow)**
Range Test (Characterizing System)

- Received signal stronger with horizontal tag orientation
- System detects pulses without issue up to 1km
  - Detection algorithm still being optimized
  - Able to hear and see pulses intermittently at 1.5 km ≈ 0.93 miles
- Detected pulse strength depends on alt, distance, and beacon antenna orientation.
# Localization Results

<table>
<thead>
<tr>
<th>Flight info</th>
<th>Bearing Error</th>
<th>Localization Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tiral Descrip.</strong></td>
<td><strong>Median</strong></td>
<td><strong>Std. Dev.</strong></td>
</tr>
<tr>
<td>UAV: 1/2-Circ</td>
<td>9.3°</td>
<td>43.8°</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>45%</td>
</tr>
<tr>
<td>UAV: Circ</td>
<td>6.7°</td>
<td>5.2°</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>12%</td>
</tr>
</tbody>
</table>

**Flight info**
- UAV: 1/2-Circ: 500 m Dist., 75 m Alt., 12 Waypoints
- UAV: Circ: 100 m Dist., 15 m Alt., 12 Waypoints

**Bearing Error**
- Median bearings and standard deviation for different localization methods.

**Localization Error**
- CM, MLE, MLM-B, RMR, M-est localization methods compared.
- Average error values for each method.
Human vs Drone Results

<table>
<thead>
<tr>
<th>Flight info</th>
<th>Bearing Error</th>
<th>Localization Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiral Descrip.</td>
<td>Dist. (m)</td>
<td>Alt. (m)</td>
</tr>
<tr>
<td>UAV: Line</td>
<td>500</td>
<td>122</td>
</tr>
<tr>
<td>UAV: Line</td>
<td>500</td>
<td>61</td>
</tr>
<tr>
<td>Human: Line</td>
<td>500</td>
<td>2</td>
</tr>
</tbody>
</table>
Outline—UAV-RT

- Current Issues with Wildlife Tracking
  - Addressing inefficiencies and risk
- Field UAV Design
  - Packable (protected when stored)
  - Simple fabrication and field repairable
- Radio Telemetry Development
  - UAV radio relay (400 ft pole for antenna)
  - Environment mapping, DOA, and estimated tag localization

- Technology Dissemination
  - Website development
    - System design (plans, tutorials)
    - Open source software and firmware

- Future Work
  - Automated localization/path planning implementation
  - Synthesis of data analysis (easy field use)
Website Overview

• Website developed to provide overview of system and detailed design and software dissemination

• Provides summary of project goals and is being optimized to create an open source environment so users can create and modify their own system

https://www2.nau.edu/uavrt-p/
Website Overview

UAV-RT

a drone-based wildlife radio telemetry system

Our Mission  Technical Stuff
Website Overview

Mission

Small Unmanned Aerial Vehicles (UAVs) have the promise to revolutionize a number of ecological research paradigms due to their low-cost ability to sample at previously infeasible locations and spatiotemporal resolutions. The UAV Radio Telemetry (UAV-RT) system is being developed to aid in field data collection for ecological applications. The UAV-RT features a recently designed, lightweight, autonomous aerial vehicle designed to carry and release radio.
Outline— UAV-RT

• Current Issues with Wildlife Tracking
  – Addressing inefficiencies and risk

• Field UAV Design
  – Packable (protected when stored)
  – Simple fabrication and field repairable

• Radio Telemetry Development
  – UAV radio relay (400 ft pole for antenna)
  – Environment mapping, DOA, and estimated tag localization

• Technology Dissemination
  – Website development
    • System design (plans, tutorials)
    • Open source software and firmware

• Future Work
  – Automated localization/path planning implementation
  – Synthesis of data analysis (easy field use)
Applying Automation

- Currently testing automated localization techniques
- System capable of localizing beacons during flight
  - Vehicle moves in response to initial estimate seeking to improve localization estimate
- Successfully simulated system
  - Currently addressing issues with live drone tests
Field Use Ready

- Synthesizing real-time DOA estimation and post processing visualization
- Designing easy to use software and interfaces that can be used as an additional tool in the field
- Creating a closed loop system
Field Use Ready
Acknowledgments

• This work was supported by NSF Award 1556417

• Collaborators:
  – Michael Shafer, PhD
  – Paul Flikkema, PhD
  – Carol Chambers, PhD

• Student Researchers:
  – Gabriel Vega
  – Kellan Rothfus

• Past Researchers:
  – Amir Torabi
  – Matthew Robertson
  – Michael Finley
QUESTIONS?
Center of mass localization

- Based on weighted average of intersection.
- Weights are the product of the mean signal power of the lines generating the intersection point

\[
\begin{bmatrix}
X_{est} \\
Y_{est}
\end{bmatrix} = \frac{1}{\sum_{i=1}^{m} b_i} \sum_{i=1}^{m} b_i \begin{bmatrix}
x_i \\
y_i
\end{bmatrix}
\]
PCA for DOA estimates

\[ \vec{P}_{a,i} = \begin{bmatrix} P_i \\ 0 \\ 0 \end{bmatrix} \]

\[ \vec{P}_{e,i} = R_i \vec{P}_{a,i} \]

\[ R_i = R_z(\phi_v)R_y(\theta_v)R_x(\psi_v)R_z(\phi_a)R_y(\theta_a)R_x(\psi_a) \]

\[ \vec{P}_e = (I - \frac{1}{n}J) \vec{P}_e^* \]

\[ \vec{P}_{avg} = \frac{1}{n} \vec{P}_e^T \]

\[ \vec{P}_e = U \Sigma W^T \]

\[ \vec{\omega}_p = \frac{\vec{P}_{avg} \cdot \vec{\omega}_1}{\|\vec{P}_{avg}\| \|\vec{\omega}_1\|} \vec{\omega}_1 \]
Bearing error study

Number of received pulses (assuming even angular distribution)

Standard deviation of PCA angular bearing error (degrees)

Time to acquire bearing estimate for pulse rate 1/s (min)

- Ideal power (dbm)
- Fading modeled power (dbm)
- PCA bearing est.

Legend:
- $K = 1$
- $K = 2$
- $K = 5$
- $K = 10$
- $K = 20$
- $K = 50$