Demo Abstract: Autonomous UAV sensor system for searching and locating VHF radio-tagged wildlife

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ABSTRACT

We consider the problem of tracking and localizing radio-tagged targets, a labor-intensive and time-consuming task necessary for wildlife conservation fieldwork. We design a lightweight sensor system for measurement of radio signal strength information from multiple radio tags. The sensor system is designed to suit low-cost, versatile, easy to operate multi-rotor UAVs. In this demo paper, we demonstrate our Unmanned Aerial Vehicle (UAV) sensor system for tracking and locating multiple VHF radio tags.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**; *Robotics*;

KEYWORDS

UAV, localization, search, radio-tag, wildlife

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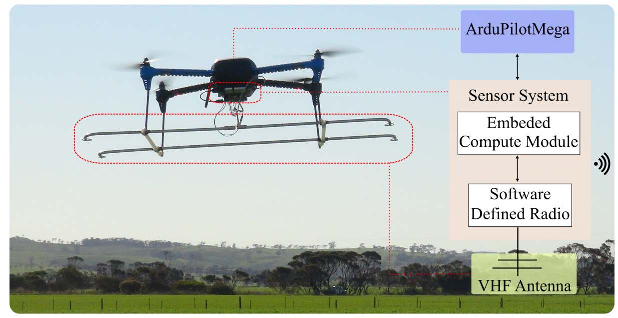

Figure 1: The autonomous UAV platform.

1 INTRODUCTION

Rapid developments in civilian Unmanned Aerial Vehicles (UAVs) have opened new frontiers in the open airspace with new application possibilities. Examples of civilian applications using UAVs, or so-called drones, including wildlife monitoring [6, 9], search-and-rescue missions [4]. The anatomy of such applications is an aerial drone platform with the ability to carry a payload consisting of specialized sensor systems such as LIDAR (Light Detection and Ranging), chemical sensors, and infrared cameras. However, realizing such applications effectively necessitates drone platforms to operate autonomously where drones are required to plan the best trajectory to carry out their mission under computational and power constraints [7].

In this demo, we focus on a new application area for autonomous sensing with UAVs. We demonstrate an application of UAVs to track and locate multiple radio-beacons. This is significant for locating and monitoring of radio-collared wildlife to support the efforts of conservation biologist to manage and safeguard endangered wildlife and ecosystems [10]. VHF (Very High Frequency) collaring is the most widely used technology for radio tagging because it is low cost and can be manufactured with various size and mass attributes to suite a large range of animal sizes [11]. Traditional tools for locating radio collard wildlife in studies require trekking through habitats to manually home in on radio collar signals using the handheld, highly directional antennas and receivers that convert radio collar signal strengths to audio signals. Indeed, an autonomous drone platform can provide a new method for conservation biologist to automate the labor-intensive and manual task of homing in on radio signals from multiple animals and provide the capability to gather more granular spatiotemporal data related to endangered species through a lower cost monitoring tool.

The only demonstrable aerial robotic system with a ground control station for localizing a *single* radio-tagged animal used bearing-only measurements from a phased array to locate a *stationary* bird [1]. The bearing-only design required a heavier payload as well as long measurement times (45 seconds per observation in [1]) to calculate the angle of arrival from emitted sources to estimate an object's location. This is because the UAV needed to be rotated for each measurement and thus consuming precious battery life for each measurement. Instead, we demonstrate an alternative approach using received signal strength information to realize a lightweight sensor and, hence, a payload to significantly shorten the measurement time (less than 1 second per observation). We employ a software defined radio to allow the scanning and detection of multiple radio collar signals to determine planning decisions to track multiple radio-tagged objects.

Early efforts to demonstrate the possibility of incorporating SDR architectures with a UAV to detect multiple transmitted signals from VHF radio-tags are reported in [3, 8]. Notably, the studies above with UAVs were not focused on real-time tracking. In [3], a UAV followed a pre-defined path to collect and log VHF collar

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signal detections. The data collected was processed after the flight to generate a heat map of signals. In contrast, [8] demonstrated a method of measuring bearing using a 3 element Yagi antenna by rotating the drone mounted receiver. In [2], a multi-UAV system was proposed to localize multiple radio-tagged animals. However, the work in [2] computes the measurement locations offline. Our receiver system is also based on a software defined radio but we collect and process the signal strength data to realize real-time tracking of VHF collared targets using an online planing method.

In this demo, we present the design of a UAV sensor system for tracking and localizing *multiple* radio-tagged objects. To the best of our knowledge, this is a first demonstration of UAV robot system for tracking and locating multiple radio-tagged objects in real-time. Our demonstration is based on our work in [7].

2 SYSTEM ARCHITECTURE

Figure 1 represents an overview of our proposed system architecture and the physical components of our system. The total system payload is 220 g, including a customized lightweight compact directional antenna, a software defined radio device, and an embedded companion compute module. The tracking and planning algorithm is performed on a ground control station to estimate object positions and navigate the UAV autonomously to improve search and localization accuracy. The ground control station communicates using a 2.4 GHz communication channel to both receive data from the UAV and send control actions to the UAV.

The aerial robot system we employ is a 3DR IRIS+ drone controlled by an ArduPilotMega (AMP) firmware. We use a HackRF One SDR capable of receiving all signals within a 10 MHz bandwidth. A discrete Fourier transform based algorithm is implemented on the Embedded Compute Module (Intel Edison board) to detect the emitted pulses from radio-tagged objects. For each of the targets, the received signal strength is extracted from the magnitude of the detected signals in the frequency domain. A log-distance path loss model with multi-path fading (MultiPath) [7] is used as the measurement model to characterize the signal attenuation. The tracking and planning algorithm is implemented on a Ground Control Station in the loop [7].

3 IMPLEMENTATION

We use a Particle Filter to implement our tracking algorithm to account for the non-linear system dynamics and noisy measurement data from signal strength measurements affected by factors such as interference and receiver thermal noise. We formulate a planning algorithm to navigate the UAV towards minimizing the uncertainty of tracked targets using the information based Rényi divergence measure [7]. Given the goal is to search and locate targets, we include a search termination criteria: an object is considered localized and ignored if its uncertainty in x-axis and y-axis is smaller than a defined bound (10 m in our case).

Figure 2 shows an instance of a search and localization result with our proposed system from a field mission conducted in [7] within a testing area of size 75 m × 300 m. The results demonstrate that our system is capable of autonomously localizing multiple radio-tagged objects, The algorithm first navigates the UAV towards object 1. After object 1 is localized, the UAV navigates towards object 2 and returns to the original home location after object 2 is determined as localized.

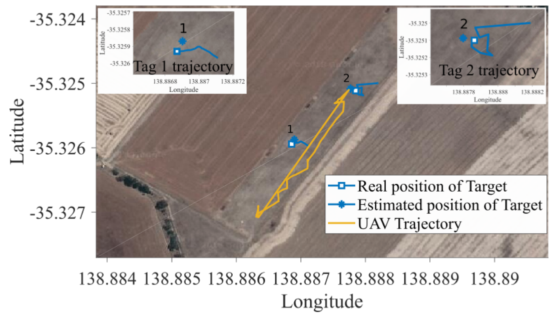

Figure 2: Field experiment results.

4 DEMONSTRATION

A full demo video can be found at [5]. For safety reasons, instead of flying the UAV indoors, we use an Unmanned Ground Vehicle (UGV) for the demo. The embedded sensor system is mounted on the UGV, and control actions are used to direct the UGV to search and localize radio tags in the field. A simple demo scenario includes: **i)** The UGV searches and localizes two radio-tagged beacons around the exhibition area. The target is considered found and localized when the position uncertainty is adequately small; and **ii)** The joint tracking and planning algorithm is executed in real-time on the ground control station, while the control actions are sent back to the UGV. The ground control station (a personal computer) will visually monitor and display the real-time tracking and localization information.

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