ECE496 Draft Proposal

Project Title: Usage of Bluetooth Low Energy (BLE) to locate drones in a swarm and control them using gestures in a motion detection system

Project Number: 2022617

Supervisor Name: Lacra Pavel

Team Names:

Mohammad Ahmed

Jun Ho Sung

Adam Pietrewicz

Natalia Sydorenko

Executive Summary

Swarm drones refer to a group of Unmanned Aerial Vehicles (UAVs) that operate together in order to complete tasks such as surveillance and mapping. The research and application field of drone swarms is of high interest to the team since there is constant room for further innovations such as increasing accuracy of drone localization and improving the reliability and robustness of drone-to-drone communication. The team was motivated to implement Bluetooth Low Energy localization technology to drone swarms because it provides more accurate localization than the usual technologies such as GPS. There are two components to this project: The first is to design and build a drone swarm that utilizes the Bluetooth Low Energy module for localization and communication. The second is to design a visual hand gesture system that allows users to control the movement of the drone swarm in an attempt to make drone swarm control user friendly and easy to use.

The application of the drone swarm is for a user to move the swarm using hand gestures in an indoor environment. In order to generate designs, the project scope, requirements, objectives and constraints have been specified for both of the project components to ensure that the drone swarm can operate for its intended application. The team's first course of action is to build the quad-rotor drones that properly take flight. It is vital that the drones weigh less than 250g each in order to be properly operated indoors without a license, and that they properly communicate with each other within a mesh network and a Ground Control Station that keeps track of the drones' states and changes the system's input (drone displacement) using a hand gesture system operated by the user. Next, the Bluetooth Low Energy modules must be tested to ensure they can send packets of data between each other in real-time, with minimal delay and inaccuracy. The main responsibility of the localization system is to ensure that the drones do not collide with each other, and the hand gesture system must accurately control the swarm to avoid collisions with users and the test environment. The hand gesture system will then be integrated with the developed drone swarm system in order to convert the user's hand gesture into swarm motion.

Motivation

Our initial motivation was to devise a project utilizing swarm drones. With this in mind, we researched state-of-the-art applications of drones such as room mapping, search and rescue, surveillance, and infrastructure inspection. We discovered that these applications mainly rely on GPS and distance sensors such as LIDAR, RADAR, and ultrasonic, which are specialized only for localization. After further research, we found that Bluetooth Low Energy (BLE) can be used to locate signal origins using Angle of Arrival (AOA) or Angle of Departure (AOD) down to centimetre accuracy in addition to sending data packets [1]. Since we were not able to find any current applications of BLE in drones and due to its comparable accuracy to GPS, it was clear that we could use BLE to combine flight control with localization [2][3].

To find an application of swarm drone control while also showcasing the localization capabilities of BLE, we decided to implement gesture control using computer vision. In industry, gesture control can be found being slowly implemented in different areas such as in automobiles, smartphones, and toys such as gesture-controlled RC cars. Currently, this area is predominated by hard-coded gestures taken from sensors such as gyroscopes (toys) and radars (cars and smartphones) [4][5]. We wanted to explore this area using AI, specifically computer vision and machine learning, so combining gesture control with swarm drones was a logical step in our ideation process.

Problem Statement

The main problem we’re solving is having cheap and accurate localization implemented in drones using only Bluetooth modules since the performance of current implementations using GPS is limited to only detecting outdoor locations and is not capable of being used as a communication source. The secondary problem is using only vision systems to detect hand gestures intended for controlling the drone swarm.

Project Goal

The project goal is to develop a scalable swarm drone infrastructure that utilizes Bluetooth AOA technology for localization and communication between 3 or more drones. Once this is met, we will expand our project to be able to detect hand gestures to output some sort of swarm motion.

Scope of Work

The first step in our project is to design the drone we will be working with. For the design, we will be using off-the-shelf parts with a Bluetooth module attached for our first project goal. With the drone

designed, we will design a system to send MAVLink commands through Bluetooth from the ground control system (GCS) to each drone [6]. We will also need to work on converting the Bluetooth packages to MAVLink commands readable by the flight controller.

After establishing the communication protocol, we need to design a swarm robotics control system for our drones. The control will have 2 main parts involved: motion planning and collision detection. To get to the desired end location, the drones will use inverse kinematics to determine the path and their orientation to get there. Since there are multiple drones, collision detection will also be implemented to modify their route to make sure they avoid each other while getting to their destination [7].

The control system will then interface with a gesture recognition system to complete our second project goal. This will include creating a data set with the desired gestures, then designing and training a machine learning model to detect these gestures. For the gesture recognition system, we will decide whether to use a camera system with a computer vision network to detect each hand digit or a dedicated sensor such as the Leap Motion sensor.

Requirement Specification

Functions:

- Each drone must be able to communicate with the ground station either directly or indirectly through a mesh network
- The GCS will be able to know the location of each drone
- The GCS must be able to detect and recognize hand gestures and send navigational directions to each drone based on their current location
- Each drone will be able to correctly move to the location using signals sent from the GCS.

Objectives:

- The gesture recognition system should be able to detect at least 5 different gestures
- The control system should be able to manage at least 3 drones
- The BLE system should be able to mesh with at least 3 beacons

Constraints:

- Each drone must weigh less than 250 grams
- The hand gesture dataset must include at least 40 images for each gesture with 5 different gestures, for a total of at least 200 images

Conclusion

With drone technology on the rise, it was clear to decide where to direct our project. Now, our main milestone will be to complete the design of our drone, so that the communication and control systems can be implemented. After this, we expect to focus on the gesture recognition system in the final few months of our project. We will need to pay close attention to the dataset gathering early on while working on the first to ensure our machine learning model will be able to sufficiently detect the desired gestures indicated.

References

(will convert to full IEEE citation in the final version)

[1] https://www.bluetooth.com/blog/new-aoa-aod-bluetooth-capabilities/

[2] https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/global-positioning-system#:~:text=Limitations%20of%20GPS,greater%20than%203%2Dm%20accuracy

[3] https://www.mdpi.com/1424-8220/21/11/3589/htm

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[5] https://jalopnik.com/bmws-gesture-controls-will-have-you-feeling-like-a-medi-1848110683

[6] https://mavlink.io/en/messages/common.html

[7] K. M. Thu, A. I. Gavrilov, “Designing and modeling of quadcopter control system using L1 adaptive control” https://doi.org/10.1016/j.procs.2017.01.046