**Laboratory Idea:**

A pre-programmed path can be made for the Crazyflie. Students will adjust this path and then the drones may encounter some kind of disturbance such as from a source of wind. Students will then change the parameters of the PID controller several times in order to get the best positional estimates. The planned and actual positions will be recorded and later analysed for errors. The goal is to reduce the errors in position and velocity as much as possible. The students will do this a number of times before ending the laboratory.

Calculations for analysis:

Root mean squared error of: position, velocity, attitude, height

Drift analysis

CrazyFlie Hardware

CrazyFlie Softwares and Control Systems:

As of now, the Crazyflie can be controlled using the proprietary software provided by Bitcraze, or through a slightly modified version of Ardupilot.

Bitcraze Software

Bitcraze provides a full, open-source software package that includes:

* Microcontroller Unit (MCU) Firmware
* NRF51288 Firmware
* Graphical User Interface (GUI) for various tasks
* Python Library

This codebase is significant

Ardupilot

To use Ardupilot on the Crazyflie requires reworking some of the hardware drivers to use different communication protocols. The NRF51 on board the Crazyflie cannot be used for telemetry and a separate radio must be used. The current solution is to install Dronebridge onto an ESP-32 C3 and connect it to the Crazyflies UART port.

ESPNow through Dronebridge can be used to directly communicate with multiple other ESP-32s through a Peer to Peer system rather than a centralized controller.

CrazyFlie Positioning Systems:

In order to reliably control the Crazyflie and perform any kind of stable flight, a positioning system is needed. There are currently 7 different options available.

IMU Integration

The Inertial Measurement Unit (IMU) can detect both acceleration and angular velocity in all 3 dimensions. By double integrating the small changes in acceleration at a high frequency, an estimate of position can be obtained. This method by itself is insufficient for reliable control due to the rapidly compounding errors produced by the imperfect sensor.

Flow Deck

The flow deck uses an optical flow as well as a TDOA (Time Difference of Arrival) sensor to estimate its ground velocity. The optical flow sensor measures how quickly pixels change as the drone moves along, which in combination with the TDOA sensor can relate to how fast the CrazyFlie is moving relative to the ground. This method provides a better estimate of velocity then solely from the IMU and can be integrated to find relative position.

Loco Positioning System

This method uses Ultra-Wide Band (UWB) ranging and communications to determine the absolute position of the Crazyflie. A transmitter sends either 6.5 or 8 GHz radio waves to a receiver. The timestamp of when the transmission was sent is picked up by the receiver which can then measure the current time and thus use the velocity of light to calculate the distance between them. By setting up several fixed “base stations” with known positions, the absolute position of the Crazyflie can be calculated using trilateration. A “tag” expansion deck is needed for the Crazyflie as well as at least 4 “anchors” to place on the ground.

Lighthouse Positioning System

The lighthouse positioning systems works the same in principle as the loco positioning system, but uses a higher frequency wave.

Motion Capture

Common Issues Encountered

* Joystick requires setup and calibration prior to use. Any USB joystick can be used but it must be set up using either the cfclient or other programs.