Indoor localization using Local Positioning Systems.

MSc.

By

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Abstract

Here goes the abstract

Dedication and acknowledgements

Here goes the dedication.

Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

SIGNED: .... DATE: ....

NOMENCLATURE

- UAV - Unmanned Aerial Vehicle.
- GPS - Global Positioning System.
- LPS - Local Positioning System.
- FCU - Flight Controller Unit.
- UWB - Ultra-WideBand.
- TOF - Time of Flight.
- PSoC - Programmable System on Chip.
- NLOS - No Line of Sight.
- TWR - Two Way Ranging.
- I2C- Inter-Integrated Circuit Bus.
- SPI - Serial Peripheral Interface.

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Chapter 1

Introduction

In recent years Unmanned aerial vehicle(UAV) usages has grown exponentially becoming common in industry and households Custers (2016). A major part of UAV applications is their ability to localise themselves in the given environment with acceptable precision and accuracy. This is a common requirement in any robotic system but UAV's are often limited by strict payload requirements and therefore have to rely on sensors that are lightweight and robust. (Mendoza-Mendoza et al. 2020) gives a good summary of physical components that are used in various vehicles but a UAV system, specifically, a quadrotor system cab be summarised as follows:

- Rotor build - This section contains parts that should be researched based on the size and physical requirements of the drone. These include: brushless motors, electronic speed controllers, frame size.

- Flight controller unit(FCU) - This acts as the mother board and brain of the quadrotor system. It collates data from various sensors, sends commands to the motors and if there is a companion computer is attached collects and sends data to it. Commercial FCU's contain the various control systems and laws required for stable flight and movement. Most have an array of sensors built in.

- Sensors - These vary from from inertial, positioning, barometric and camera. Aside from inertial and barometric sensors that are present in most FCU's, sensors are chosen based on the environment and use case of the system.

- Companion computer - In some cases higher level processing is required by the system to execute autonomy and a secondary computer is used to do this.

- Transmitter and Receiver - This is used to implement manual control over the drone by a user.

Further delving into the sensors, we can classify UAV's based on their operating environment, indoors or outdoors. These give rise to two forms of localisation and navigation systems:

- Global Positioning Systems (GPS) - As the name suggests this setup uses GPS as well as other sensors.
- GPS-denied - These systems do not have access to GPS due to their operating environment.

In outdoor applications GPS provides a reliable and fairly accurate way to localise with use of several other sensors. However, indoor applications are denied the benefits of GPS and often must use other sensors for the task of localisation. Utilizing a similar concept of triangulation used by GPS a local positioning system(LPS) can be used for indoor environments. (Labs 2018) has developed a commercial system that utilizes Ultra-WideBand technology(UWB) with a bandwidth of $\approx 500MHz$.

With indoor environments users have more control of the environment so a LPS can create a feasible solution for indoor localisation for UAV's/robots operating there. The core idea of this research would be to integrate a commercial LPS directly into an existing FCU to produce accurate position estimates that can be used for autonomy. The measurements from the LPS would then be transformed into observations of the state of the UAV and fused with other observations from other sensors. This fused pose estimate would then be fed into the companion computer for off-board processing.

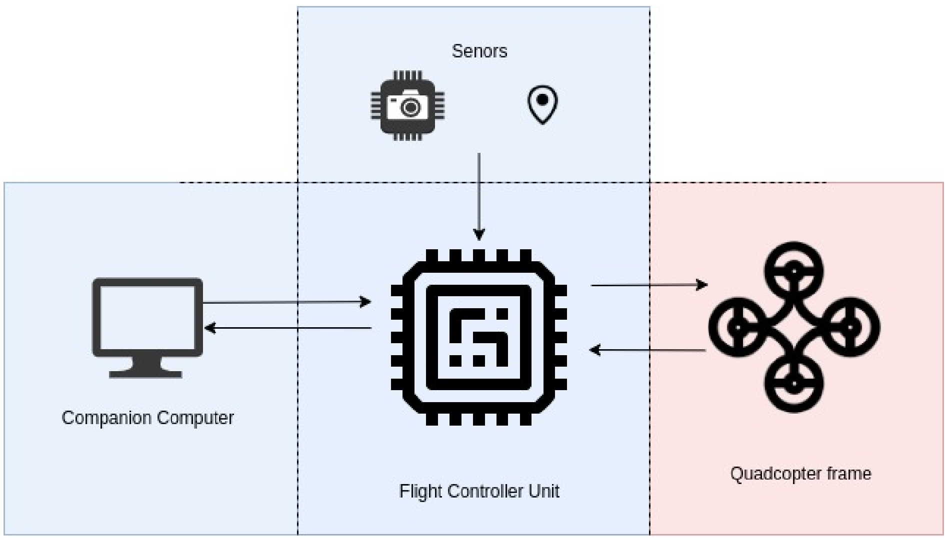

Figure 1.1: The typical setup for an autonomous UAV.

Figure: 1.1 shows a typical setup for UAV. Parts of the system highlighted in blue represent systems that would be worked on during the course of this research. The idea is that the system being designed should provide localisation data which should be independent of the rotor build. These will be further scoped in the upcoming sections but it will involve doing a quality exercise of the LPS tp determine measurement uncertainty and limitations, writing additions or modifying the firmware of the FCU to integrate the LPS and setting up the piplines for a companion computer to receive the pose estimates and use them.

1.1 Aims & Objectives

In 1 we briefly touched on what would be addressed over the course of this research. Expanding on that, the research would entail the use of the commercial version of an UWB sensor for positioning from Labs (2018). At a high level the project and be split into three modules that must be researched, unit tested and finally integrated. Figure 1.1 highlights the major systems within the project and are as follows:

- The Pozyx LPS providing measurements that will be used in localisation.
- A flight controller collating fusing various observations from sensors to provide a pose estimate.
- A companion computer to visualise and utilise the pose information in a meaningful manner.

From these systems and the overall aim of indoor localisation the following objectives were created:

- Evaluation and qualitative analysis of the LPS, documentation limitations from previous done work and current physical setups as well as compare with other ranging standards.
- Based on the qualitative analysis and experiments determine the best configuration in a household to place the anchors for the system.
- Use the incoming data from the sensors to produce a suitable measurement/observation model for the pose of the system.
- Relay the data to a flight controller unit via a suitable hardware interface.
- Delve into the firmware of the flight controller and apply sensor fusion algorithms on the flight controller to provide pose estimates.
- Pipe the pose estimates to a companion computer for visualisation and higher level control of a UAV.

All of these objectives can be completed without flying the UAV autonomously. Given the current situation and time-frame it was determined that setting up the pipelines to visualise the localisation in realtime from the companion computer is adequate for the last objective. Furthermore, with the autonomous flight being out of scope of this project much of the work fell into software engineering to achieve the overall aim. Broadly, this means delving into the software libraries and interfaces for the Pozyx sensor, modifying and making additions to the Ardupilot flight stack to integrate the Pozyx sensor with the (pixhawk?) FCU, and finally digging into the MAVLINK protocol and libraries to use the pose estimates on a Raspberry Pi 3 Model B+ PSoC. To achieve these objectives a solid software engineering aproach would need to be applied with familiarity of Python and C++ programming languages.

1.2 Background Research

Indoor localisation has become a core part of many system in recent years. These range from robotics, multimedia, logistics and sporting systems. Modern localisation systems can be split in active or passive systems, active systems require the system being localised to have electronics to either process or send information that will be used to determine location. In passive systems the position is determine based on a variance of a measured signal or image data. As noted by Deak et al. (2012), some of these techniques include, Received Signal Strength Indicator (RSSI), Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Angle of Arrival (AOA). The Pozyx commercial system uses UWB signals with a TOF technique in order to determine the position of a receiver (tag) in a network of transmitters (anchors). Since processing is done on-board the tag, it falls under the active localisation category. Active systems are ideal for indoor localisation systems for drones since the positional data can be fed directly to FCU's or companion computers in order to correct pose estimates calculated by the system directly.

As noted by the producers of Pozyx the core of the system uses a communication bandwidth of $\approx 500MHz$, this results in pulses of $0.16ns$ wide. Assuming that speed of light is $299792458ms^-1$ we get pulses of length $0.04797m$ which is very small and hence robust to noise from reflections. The major factors affecting the performance of the system would be materials that would slow down the signals before they reach the tag. So No Line of Sight (NLOS), conductors and changing mediums of travel are noted to affect the performance the most.

With increasing complexity of FCU's it is possible to do relatively dense calculations in a real time scenario without delegating them to a separate processing system. This is beneficial to indoor drone systems since they need to be small and maneuverable. A standard FCU comes equipped with several standard communication interfaces (I2C, Serial, SPI) so integrating external sensors is possible. Furthermore, multiple autopilot firmware provides a Hardware Abstraction Layer (HAL) making any sensor integration developed on one unit easily ported to another system. Additionally, on board libraries contain sensor fusion implementations (Extended Kalman Filter (EKF)) that can combine the Pozyx data and on-board sensor data to provide fairly accurate positional data while in motion.

Chapter 2

Literature Review

2.1 Indoor Localisation Systems

Passive Systems

In summary, passive systems do not require the object being tracked to have some of electronics on them to do positioning. Some examples of passive systems are (Deak et al. 2012):

- Computer Vision and Imaging systems.
- Tactile and contact sensors.
- Attenuation of signals.
- Differential air pressure.

A common example of computer vision based localisation is to use a setup consisting of multiple cameras in a space trying to detecting a single object. Using the intrinsic and extrinsic properties of each camera it is possible to determine the transform to the object in a given frame with relatively high accuracy. A prime example of this is the commercial VICON motion capture systems. *Visual Inertial Odometery* (n.d.) shows a drone application in which the UAV is positioned via using a VICON motion capture system. Figure 2.1 shows the simplified setup, it should be noted that the UAV must be equipped with specialised marker that is used to identify it. Furthermore, the positions are fed to a companion computer connected to the autopilot system. The VICON setup provides highly accurate positions and is often used to gather ground truth positional data to compare to other positioning systems. The additional requirements of the VICON systems, however, do not make it feasible for indoor applications.

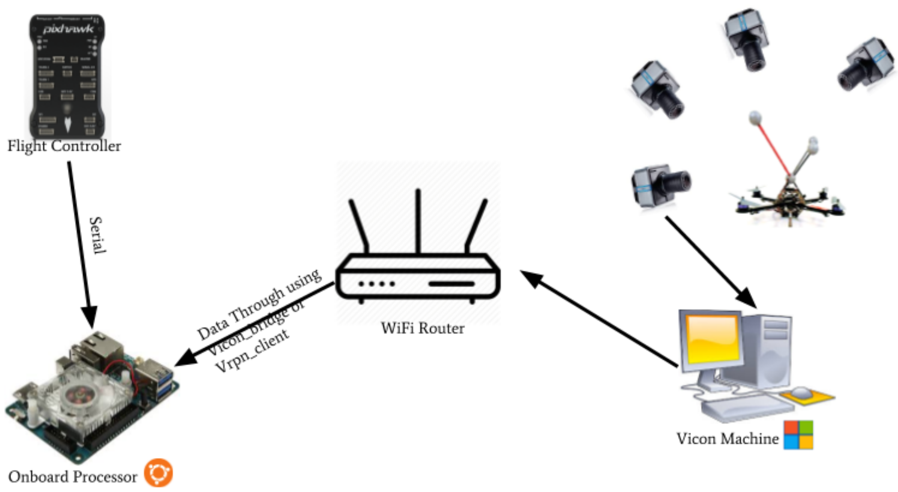

Figure 2.1: VISON setup for position of a UAV. (`https://aerial-robotics-iitk.gitbook.io/wiki/estimation/setup-with-vicon`)

Active Systems

In contrast to passive systems, active systems have the object being positioned equipped with electronics. Many indoor localisation techniques use this and some examples are Deak et al. (2012)

- Radio-frequency identification
- UWB
- Wireless Local Area Network
- Bluetooth Low energy (BLE)

Many of these setups use an anchor and tag configuration. The tag receives signals from multiple anchors and triangulates the tag.

An approach using and comparing UWB and BLE is developed by Jiménez & Seco (2017). Both methods are combined with a dead reckoning system to improve accuracy.

2.2 Pozyx - Behind the Scenes

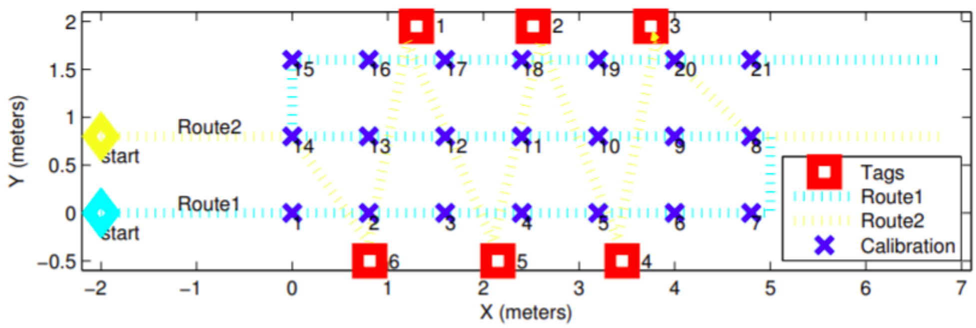

Figure 2.2: Setup used to compare UWB and BLE performance in a museum.

APPENDIX A

APPENDIX A

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