# Demo: In-flight Localisation of Micro-UAVs using Ultra-Wide Band


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## Abstract

In this demo we propose to use the UWB technology on micro UAVs as a way to estimate inter-drone distances. This information is the fundamental building block for a self-maintaining formation flight of a UAV swarm. We present preliminary results for the computation of distance between UAVs and we show an UAV flying and computing its position in function of three fixed anchors.


## 1 Introduction

UAV swarms are usually controlled using high precision motion capture when indoor [3], or Global Navigation Satellite System (GNSS) when outdoor [1]. However, the hardware is expensive, energy-hungry, and for indoor, extra hardware needs to be installed in the infrastructure (so limiting its use in this area). We propose here the use of Ultra-Wide Band (UWB) technology for computing distance measurement between UAVs, which will then be used for estimating their relative position, and maintaining a swarm structure when flying. Combined with the IEEE 802.15.4-2011 PHY layer and its definition of ranging marker, UWB can perform distance measurement with a precision down to 10 cm within a 250 m range. It combines good obstacle penetration, and resilience to both multi-path effects and interference from other wireless technologies [4].

The main challenges in using UWB for computing the relative position of UAVs in a swarm are:

- Measure the distance between UAVs in flight with good precision. At least three packets need to be exchanged between two UAVs in order to compute the distance between them, while they are both in movement.
- Compute UAV position fast and efficient. Since distance measurements have to be performed with at least three other UAVs in order to compute a position (using multilateration) several packet exchanges have to be made between the UAVs that form the swarm, which can lead to collisions, or network saturation.
- Eliminate the use of any external infrastructure. Computing the precise location of an object usually needs the knowledge of at least three fixed points, known as anchors. The UAVs inside a swarm need to be able to compute their position relative to a leader, without any external help.

We present here some preliminary results towards reaching our goal, which cover the first two challenges mentioned above: distance and position computation.

## 2 Experimental Setup

In the experiments that we present here we used the Crazyflie micro UAV (weight: 30 g, width: 10 cm)[1] that integrates a standard Inertial Measurement Unit (accelerometer, gyroscope, magnetometer, high precision pressure), to which we added the laser ranger for the Z axis, and the Decawave DW1000 UWB radio module[2] (see Fig. 1). We differ from the Bitcraze Loco setup, as our goal is to remove fixed anchors and compute distances inside the swarm.

Figure 1: Crazyflie + UWB

## 3 Distance Measurement Between UAVs

In theory, distance between two UAVs could be measured by exchanging one packet and computing its propagation time (difference of time between its transmission and its reception at destination), if they both have the same clock (pico-second precision is required for measuring centimeters). Unfortunately, in our case, the clocks of the UAV present some manufacturing defects and frequency drifts,

[1] https://www.bitcraze.io/crazyflie-2/

[2] https://www.decawave.com/product/dwm1000-module/




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consequence of the cheap hardware, which makes this approach not possible.

To mitigate this problem, we use a Symmetrical Double-Sided Two-Way Ranging (SDS-TWR) protocol [2] that performs a round-trip on each side of the measured end points and computes the time difference between the two packets, which increases complexity, and delay between consecutive measurements.

**Influence of Multi-path.** We made a series of experiments in order to confirm the resilience of UWB technology to multi-path interference in our scenario. The only problems that we encountered were an increase in the measured distance values when the UAVs were near the ground level. If we consider the two-ray ground reflection model, the break-point where distance measurements start to be altered can be calculated in function of the distance from the UAV to the ground ($h_t$ and $h_r$), and the radio frequency ($f$):

$$d = 4\pi \frac{h_t \cdot h_r}{\lambda} \quad with \quad \lambda = \frac{c}{f}$$

As we can see in Fig. 2, for a height of 12 cm and a UWB channel 2 ($f \simeq 4$ GHz), the break point is at $\approx 2.41$ m. As the UAVs do no usually need to fly at such low distances, this should not be a problem.

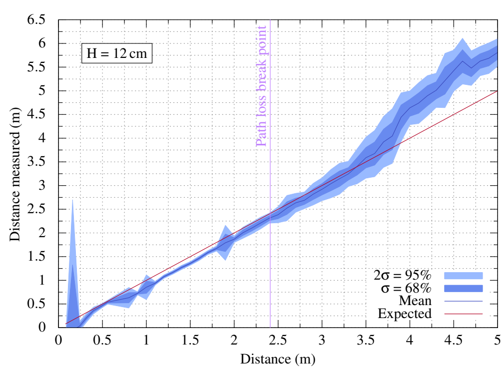


Figure 2: Distance accuracy near ground level

**Influence of UAV Orientation.** As the DWM1000 antenna has its specific radiation pattern[3] and the Crazyflie hardware on which it is attached could affect the radio signal, we wanted to check the impact of the hardware orientation on the distance measurement. We compared the distance distribution, according to different orientations (0°, 90°, 180°, 270°) for UAVs situated 1 meter apart. The results show similar values, with a normal distribution centered near the expected distance (Fig 3). Consequently, the orientation effect is negligible for a micro-UAV of this size.

## 4 UAV Localization using UWB

To compute the localization of an UAV in the horizontal plane we need to know the distance to at least three different UAVs (or anchors) whose exact positions are known. Considering the presence of multiple UAVs in a swarm who need to compute their localization, and that using SDS-TWR does not make it possible to perform multiple measurements

[3] https://www.decawave.com/sites/default/files/resources/DWM1000-Datasheet-V1.6.pdf

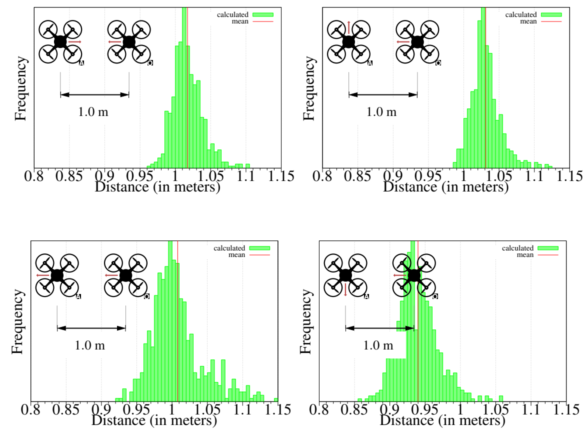


Figure 3: Distance distribution according to UAV orientation

at the same time (compared to a simple packet broadcast), there will be a high number of packets exchanged between UAVs, so a mechanisms has to be put in place for avoiding packet collisions. We propose to use a token-based algorithm that schedules the order in which UAVs perform their set of distance measurements using SDS-TWR (Fig. 4).

At the end of the SDS-TWR packet exchange, the UAV piggybacks in the last packet (which contains the calculated distance) its own position and the standard deviation (which will be zero for the anchors). Finally, we use a multilateration based location estimation in which this received information (i.e., the distance, position, and standard deviation) is fed to the Crazyflie's existing Kalman filter, which combined with the IMU information estimates its current position.

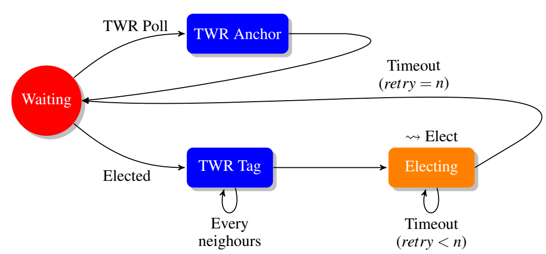


Figure 4: UAV state machine

## 5 Acknowledgments

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## Demo Presentation

Our demo consists of at least four UAVs (depending on the in-situ conditions), out of which three will be fixed on the ground and used as anchors forming an orthogonal axis in a 4mx4m area. One or more UAVs will fly and compute its relative position with regard to the anchors (Fig 5). To avoid multi-path influence we fix the anchors at 12 cm above ground level and the altitude for the flying UAVs at 1 m. The video[4] (Fig. 6) illustrates the demo.

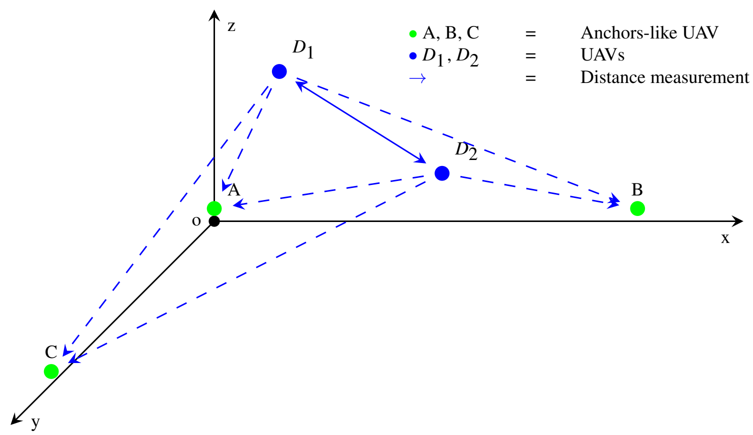


Figure 5: Demo setup with 2 UAVs 3 anchors

Figure 6: Demo with 1 UAV and 3 anchors

[4]Video: https://www.youtube.com/watch?v=wJsGsIPM14U