In-flight Localisation of Micro-UAVs using Ultra-Wide Band

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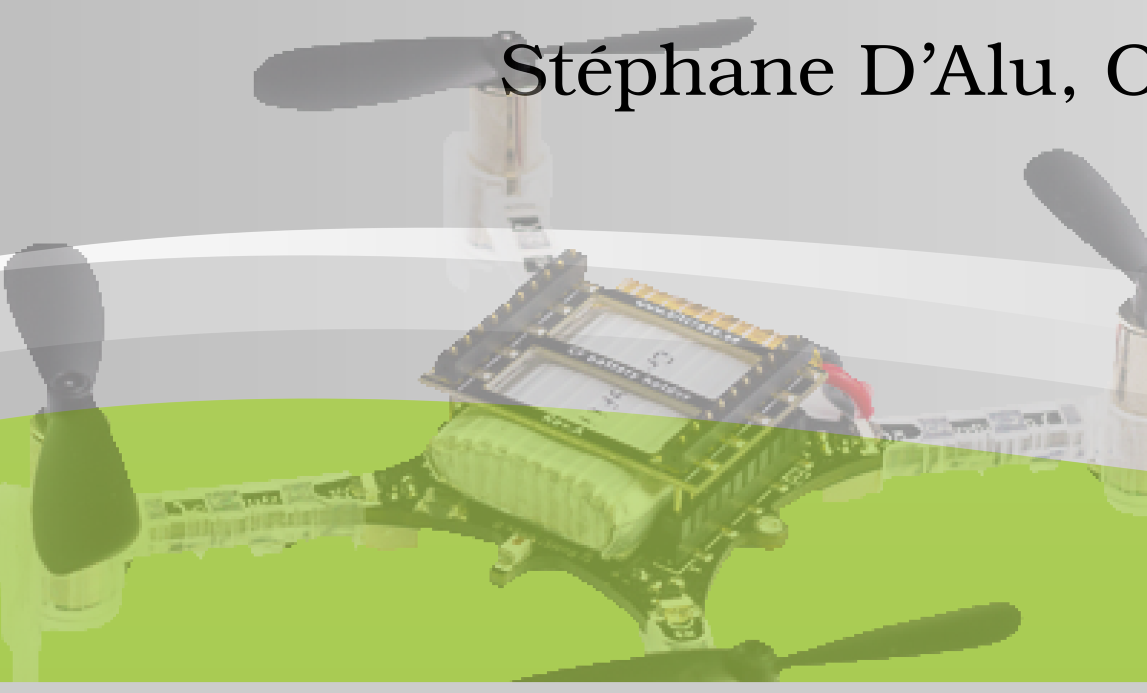


Demo presentation

Goal: self-maintained formation flight using inter-drone distances

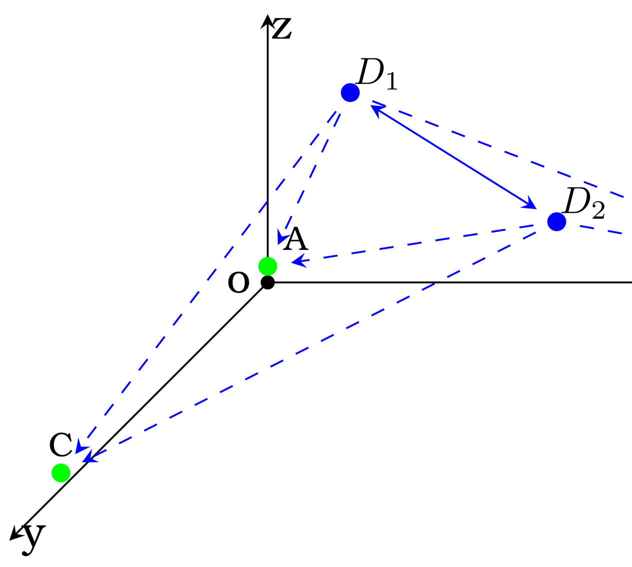
- 5 UAVs (2 flying, 3 grounded)
- measurements and control by Ultra-Wide Band [4]

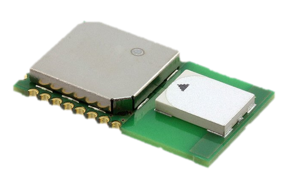
Implementation:

- Distance measurement using UWB time of flight
  - SDS-TWR to avoid clock synchronisation
  - Medium sharing using a token-based algorithm
- Position estimation using Crazyflie Kalman filter

Hardware:

- Crazyflie
- DWM1000 (loco deck)
- Laser ranger for Z axis





DWM1000
UWB radio chip

Crazyflie

Problems and goals

- Perform localisation without using an external costly localisation system (Indoor: motion capture [3], Outdoor: global navigation satellite system [1])
- Perform distance measurements inside the swarm using Ultra-Wide Band time of flight
- Manage radio access to the medium (avoiding packet collisions inside the swarm)

References

[1] M. Andrianarison, M. Sahmoudi, and R.Jr. Landry. "New Strategy of Collaborative Acquisition for Connected GNSS Receivers in Deep Urban Environments". In: *Positioning* 9 (2018), pp. 23–46.

[2] M. Pelka et al. "Evaluation of time-based ranging methods: Does the choice matter?" In: *2017 14th Workshop on Positioning, Navigation and Communications (WPNC)*. Oct. 2017, pp. 1–6.

[3] James A. Preiss et al. "Crazyswarm: A Large Nano-Quadcopter Swarm". In: *IEEE/RSJ International Conference on Intelligent Robots and Systems IROS*. 2016, pp. 3449–3450.

[4] Tingcong Ye et al. "Experimental impulse radio IEEE 802.15. 4a UWB based wireless sensor localization technology: Characterization, reliability and ranging". In: *IET Irish Signals and Systems Conference*. 2011.

Distance measurement

Method: propogation time (Time-of-Flight) of exchanged packets

Theoretically possible with 1 packet
⇒ requires pico-second synchronized clocks for centimeter precision

In practice use of multiple packets [2] to:

- cancel clock offset
- minimise error due to clock drift

Source of errors in Time-of-Flight

- Clock synchronisation
- Frequency drift
- Clock drift
- Motion

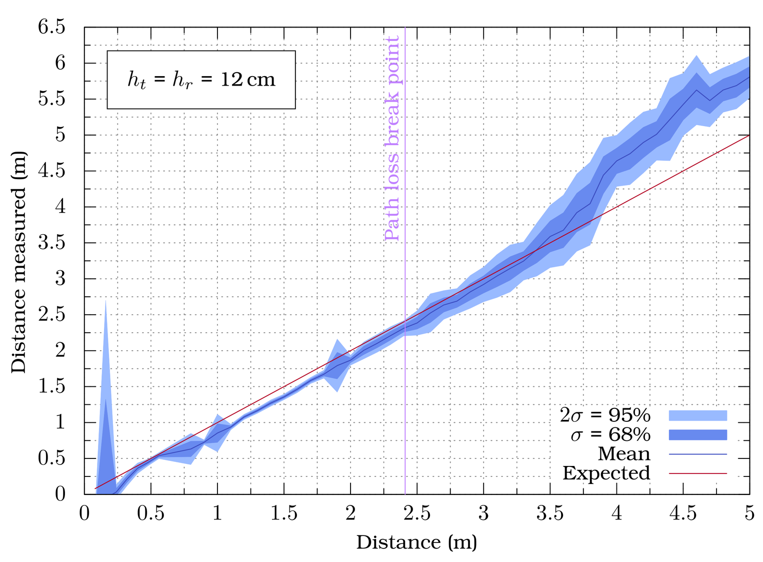
Solved by algorithms

- Antenna
- Voltage
- Temperature
- Received signal level

Solved by calibrations

Resilience of UWB technology to multi-path interference

Distance measurements start to be altered after the path loss breakpoint



Two-ray ground reflection model:

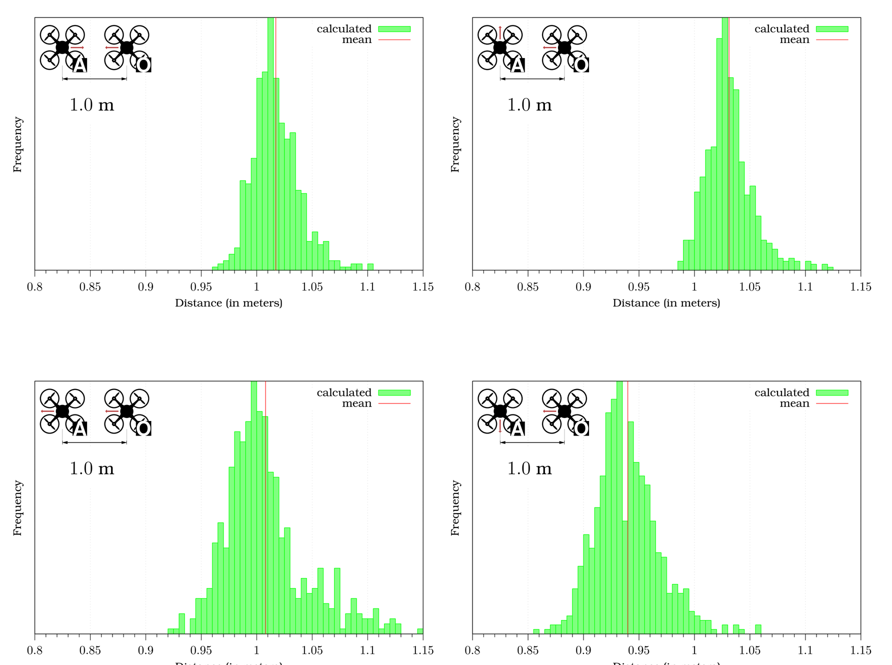
d = path loss breakpoint
h_t, h_r = antenna distance to the ground
f = radio frequency

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

Height = 12 cm, UWB channel = 2 ($f \simeq 4$ GHz) ⇒ breakpoint ≈ 2.41 m.

⇒ UAVs do not usually need to fly at such low distances, this should not be a problem.

Impact of UAVs' orientation



Differences are due to:

- Antenna specific radiation pattern
- Antenna influenced by surrounding hardware

Similar results, normal distribution centered on expected distance

⇒ Orientation effect is negligible

UWB Network communication

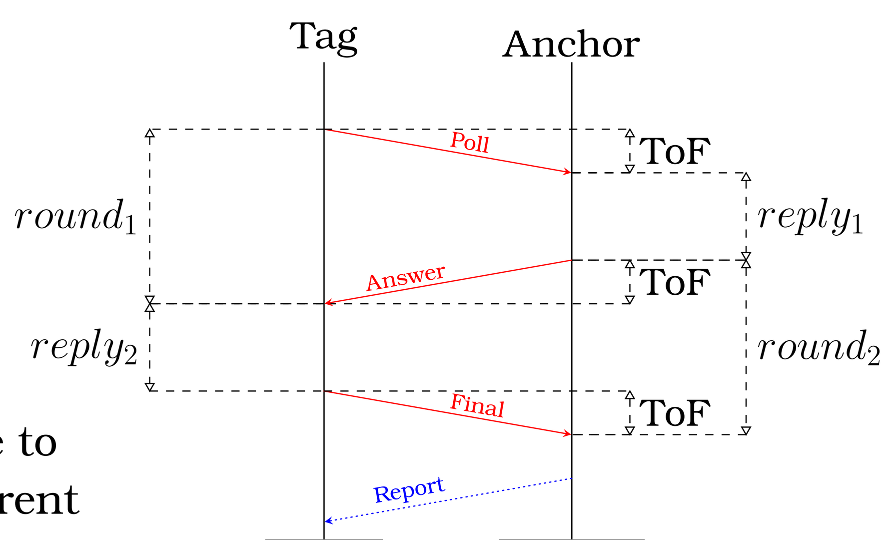
Symmetrical Double-Sided Two-Way Ranging (SDS-TWR)

Benefits:

- avoid clock synchronisation
- minimize error due to clock drift

Disadvantages:

- requires 4 packets exchanged
- increased latency
- increased risk of packet loss due to collisitions in case of concurrent measurements

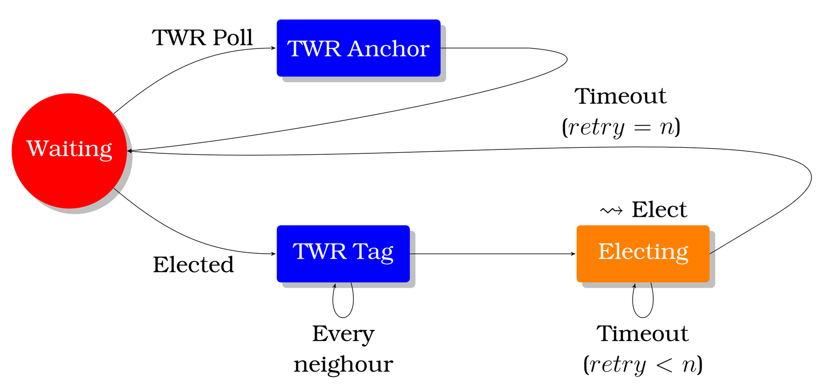


Proposition of medium sharing using a token-based algorithm

Goal: avoid collisions due to the high number of packets exchanged between UAVs

⇒ schedule the order in which UAVs perform their set of distance measurements

⇒ take packet loss into account



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