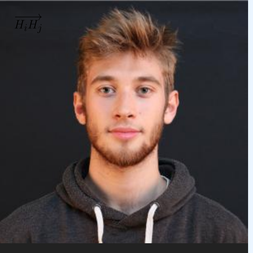

Tracking of common dolphins *Delphinus delphis* using TDoAs of signals recorded by a small hydrophone array

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Context

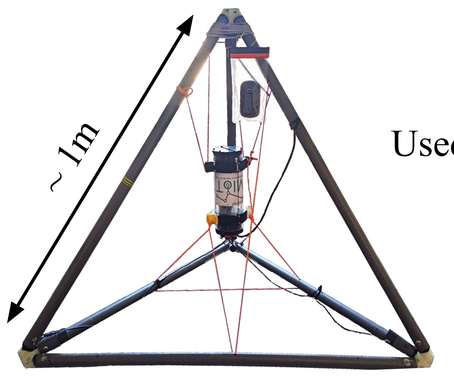
In the Bay of Biscay, France:
- 4.000-8.000 *D. delphis* by-catches/year since 2016 **[1]**
- Acoustic repellent devices (pingers) are being developed to try to limit these accidents
- The effects of pingers on dolphin behaviour and movements is **poorly understood**
- Fishermen wonder how dolphins move around their fishing gears

Objective

To **track** the movements of dolphins during experiments at sea with a **bio-inspired beacon [2]** using time delay of arrivals (**TDoAs**) between hydrophones.

Method

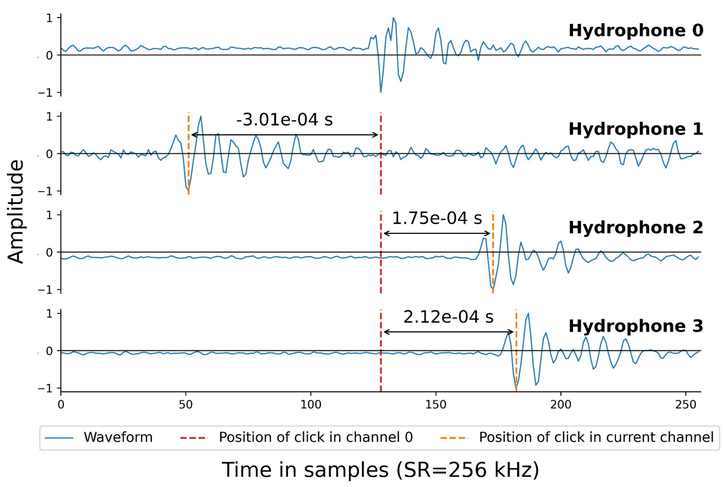
Audio data is recorded by an **antenna**:
- 4 hydrophones Cetacean research™ (3 SQ26 and 1 CR3)
- Records at 256 kHz using a custom soundcard **[3]**



Used in 2021 and 2022 off the coast of Brittany, France

⇒ After a detection of clicks **[2]** recorded by the antenna, the geometric steered response power (**GSRP**) method **[4]** is used to estimate TDoAs.

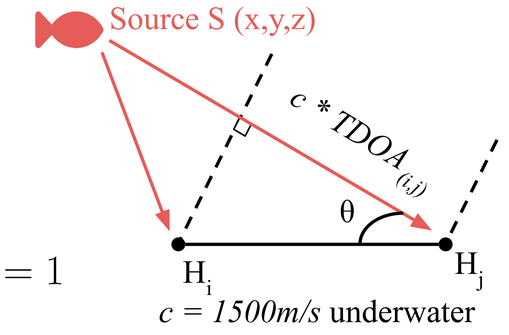
Fig 1: **TDoA estimation** around detected clicks



Results

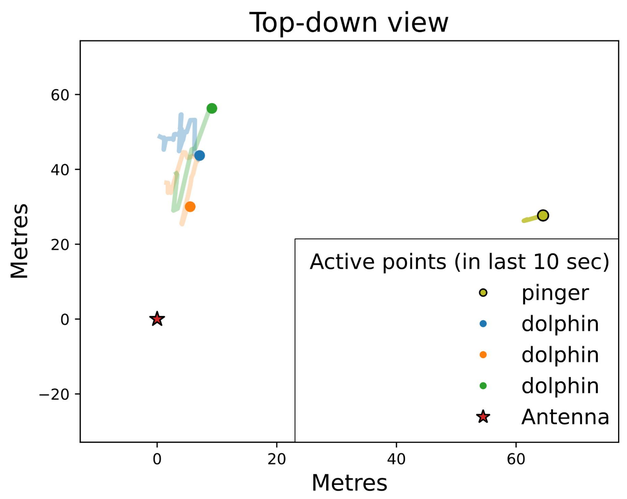
Using each combination of hydrophones (i, j), we solve this **multilateration** problem **[5]**:

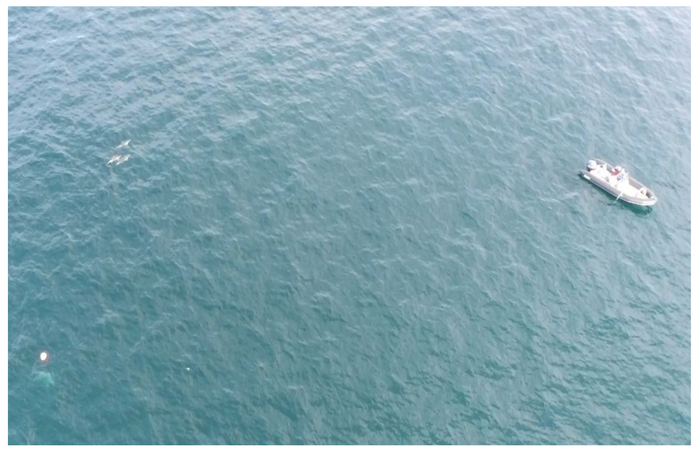
$$\frac{c * TDOA_{(i,j)}}{H_i H_j} = \overrightarrow{S} \Rightarrow \overrightarrow{S} = [r, \theta, \phi], \text{ with } \left\| \overrightarrow{S} \right\| = 1$$



Cartesian coordinates (x, y, z) are converted to spherical coordinates (r, θ, ϕ).
θ and ϕ are the azimuth and elevation angles of arrival (**AoA**). r is the distance to S.
↪To estimate r, an algorithm optimizes a loss function that clusters several predicted positions together to find the distance **r** that minimizes speed changes between points.

Fig 2: Estimated **positions** using TDoAs VS **drone** image





Discussion

Using a **compact 4-hydrophone array**, TDoAs can be estimated with enough precision to **obtain AoAs** of click sources. An estimation of the distance to these sources can be given, but is less reliable.

Our observations show that dolphins **orient themselves to echolocate** towards the **bio-inspired beacon** when it is active, then calmly leave the zone. Interestingly, dolphins are sometimes not echolocating (or at low levels) until beacon activation, to which they respond by clicking.

With this method validated, we plan to use a **5-hydrophone array [5]**, wider, to track dolphins in the water column and around fishing nets with **more precision**.

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