LOW-COST BIOTELEMETRY TRACKER FOR CETACEAN MONITORING

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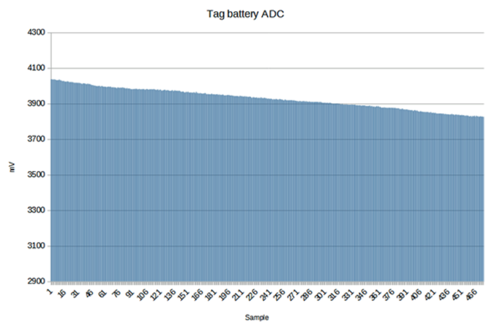
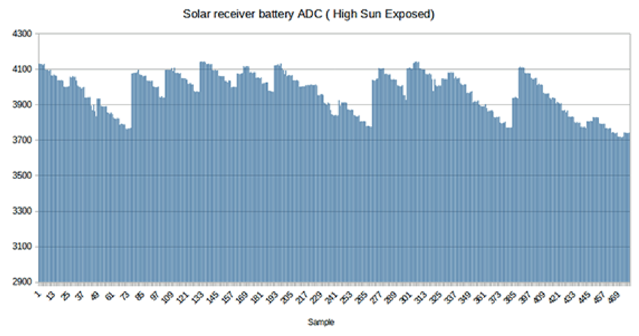
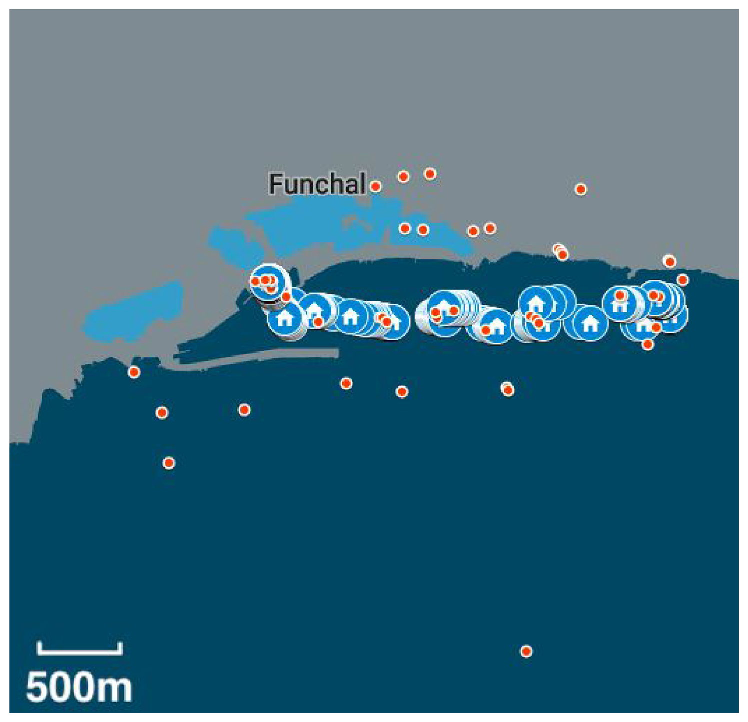




• ***Costs:*** Biologging and biotelemetry are essential tools to understand marine species and contribute to our understanding of the marine ecosystem as a whole. Biotelemetry tags are not massively-produced, they are often tailored for specific applications and remain relatively expensive. Despite the considerable costs of biotelemetry devices available on the market, the **Triton tags are developed at reduced prices**, as shown in the table.

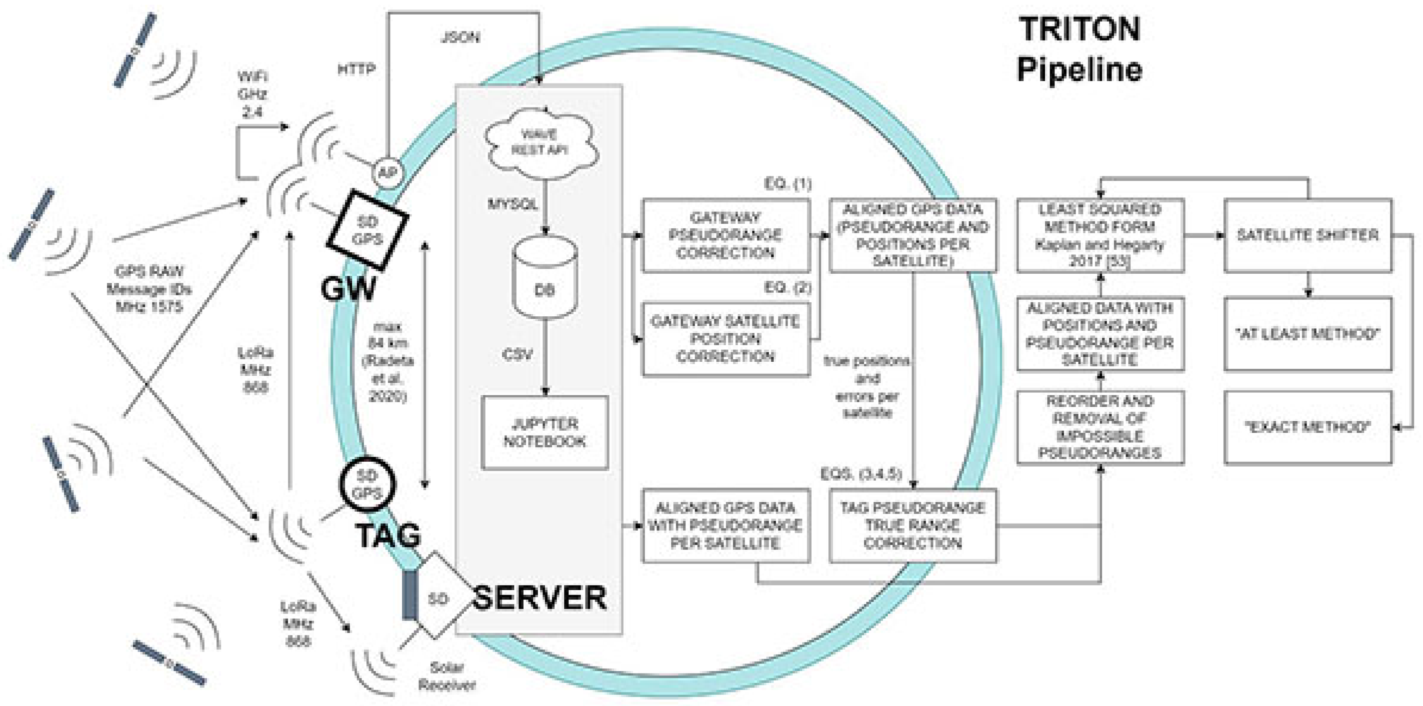
	TRITON	
Componentes	Whale Tag	Turtle Tag
ESP32 with LoRa Tag	40	40
Expansion Board	10	10
GNSS Receiver	15	15
IMU	20	20
SD Card	10	10
Antenna	5	5
Capacitive Sensor	5	5
Pressure Sensor	250	-
Battery	10	20
Programmer Board	5	5
FTDI	5	5
Golden Plated Pins	7	7
Electric Antenna	142	142
Solar Antenna	142	142
Total	€ 666,00	€ 416,00



•***Abstract:*** Biologging and biotelemetry are of great importance in cetacean movement ecology studies. While biologging methods are mostly used for assessing cetacean large- or fine-scale patterns, they remain laborious and costly in both obtaining access to data (in case of satellite tags) and retrieving the tags after detachment (in case of short-term suction-cup tags). Ubiquitous computing, Internet of Things (IoT) and open radio communication protocols such as Long-Range (LoRa) provide opportunities for the creation of robust, low-cost sensors to study cetacean movement ecology and their behavioral patterns. In this work, we present progress in the development of a low-cost biotelemetry device for monitoring cetacean movement. **We design a telecommunication system based on IoT and LoRa, obtaining a battery autonomy of 66 days when using GNSS (long-term tag) and 5 days when adding pressure and Inertial Measurement Units (IMUs) sensors (short-term tag).** We present a custom-made location estimation pipeline which in seconds allows us to interpret the raw satellite signals for decoding the position of the tag at the sea surface. We performed in-situ validation by means of tracking vehicles, vessels and snorkelers, obtaining a median average error of 100m distance. We provide a roadmap, discuss faced challenges, paving the way towards the application of the proposed system on cetaceans.

Keywords: Cetaceans; Movement Ecology; Ubiquitous Computing; Internet of Things (IoT); Biologging; Biotelemetry; Remote Sensing; LoRa; Snapshot Receivers.

- **Demonstrated low-cost technology in-situ including tag, solar and electric receiver named TRITON;**
- **First deployment of IoT and LoRa on Sperm Whale (Physeter macrocephalus);**
- **Initial tests conducted on tracking vessels median error 100m;**
- **Demonstrated simplified pseudoranging location estimation pipeline;**
- **Obtained battery autonomy until 66 days with deep sleep;**



• ***Devices were positioned in three distinct positions***. The gateway and solar receivers are in known fixed locations, and the tag is attached to our tracking object.

The gateway and tag receive raw data transmitted by the satellites, however, the gateway is also responsible for forwarding to the server the received LoRa messages with the data from the tags. Additionally, the system contains solar receivers, that can be placed in remote areas without the need for any infrastructure, electricity or an internet connection, these receivers store the data sent by the tag on an SD card to be later retrieved by the user using a hotspot from any smart device, e.g. a smartphone.

The gateway has constant access to GPS data, while the tag tries to fetch the data whenever a signal is able to be transmitted, therefore the gateway has information regarding the positions, velocities, and pseudorange of the satellites as well as clock bias indicators to correct the values received.

Conversely, the tag is only able to process pseudorange measurements between itself and each satellite.

As a consequence of the aforementioned data availability, we are able to correct the values received by the gateway and calculate the error associated with a specific satellite in a single instant.

Since the position of the gateway is known, the difference between the true distance to the satellite and the pseudorange received is the error of that satellite. Based on this information, we create pairs of data using the GPS time and satellite IDs to merge data of the gateway and tag. The data is composed of the positions of the satellites and errors calculated with the gateway data and the pseudoranges of tag.

Before proceeding with the linearization based on the least square method from Kaplan, we order satellites based on their distance to the tag and remove satellites which are too far away to provide viable measurements.

Finally, we compute and analyze results with two methods, namely the "at least" method, where we use at least n amount of satellites and the "exact" method, where exactly n satellites are used in the linearization.

• ***The results are evaluated based on their mean average error*** to real position and the percentage of correct estimations. We compare the estimated positions of the tag with the ground truth obtained with the latitude and longitude from the GNSS sensor, such can be seen in the map.