SnapperGPS A Small, Low-Cost, Low-Power Wildlife Tracking System

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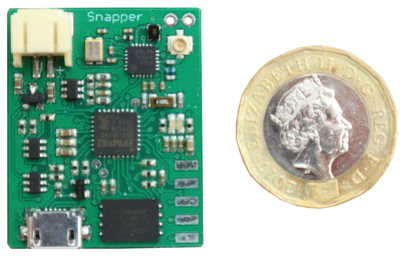
Motivation

- Biologists and conservationists use global navigation satellite systems (GNSS), e.g., the GPS, to track animals and study their behaviour.
- Existing tracking devices are often expensive ($100–$10,000) and require heavy batteries for long-term deployments.
- This prohibits studies with many animals and is our motivation for developing SnapperGPS.

- SnapperGPS aims at being a cheap, small, and low-power tracking solution.
- Its core idea is to make the hardware as simple and as energy-efficient as possible.
- We achieve this by doing as little signal acquisition and processing on the device as possible.
- Instead, SnapperGPS provides a web service that processes the signals in the cloud.
- This allows us to build a bare-bone receiver for <$30 that runs for >10 years on a coin cell.



A SnapperGPS GNSS receiver

Snapshot GNSS

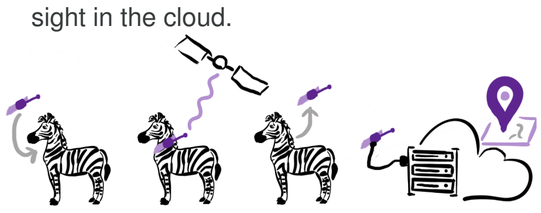
Traditional GNSS

- Spends seconds or minutes
  - acquiring satellites,
  - tracking satellites,
  - decoding data from the satellites (signal transmission times, satellite orbits, . . .),
  - calculating receiver-satellite distances from signal travel times, and
  - estimating the receiver position from its distances to multiple satellites;
- Carries out all steps on the device;
- Consumes significant time and energy and requires complex hardware.

Snapshot GNSS [4], e.g., SnapperGPS

- Captures short 12-millisecond satellite signal snapshots from time to time;
- Samples the signals with a very low resolution to reduce hardware complexity and the amount of captured data;
- Stores the raw signal snapshots until the tag is recovered;
- Uploads the raw data to our cloud service after recovery;
- Calculates the track of the animal in the hindsight in the cloud.

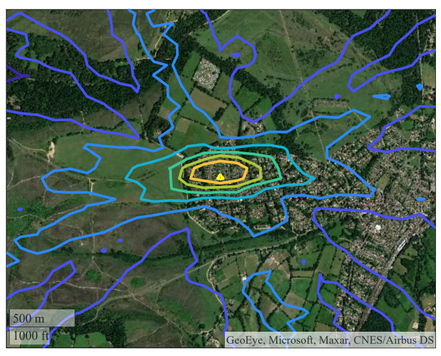
The SnapperGPS workflow ⟶



Robust Algorithms

- The main challenge for the cloud segment is to estimate a location from a satellite signal snapshot that is too short to decode a signal transmission timestamp.
- Instead, snapshot GNSS uses the phase of the periodic code that each satellite broadcasts to extract information about the signal travel time and hence the receiver-satellite distance.
- SnapperGPS faces the particular challenge that the hardware records signals at a much lower resolution then any existing system, which produces outliers.

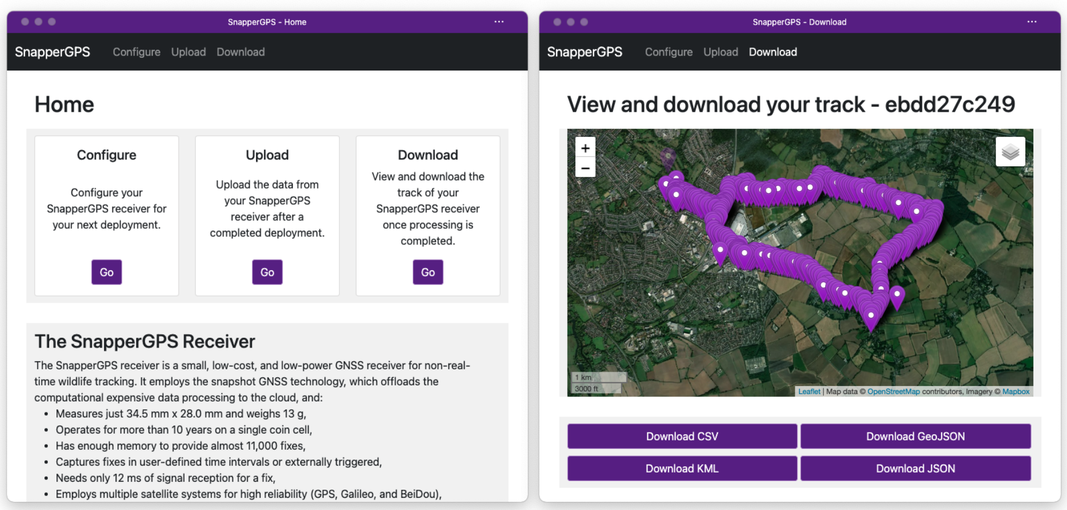
- To robustly solve the code-phase-based positioning problem, we implement three alternative approaches based on probabilistic models [1].
- The first one adds a Bayesian satellite selection strategy to the traditional non-robust least-squares approach to satellite navigation.
- The second one employs a mixture model and maximum-likelihood estimation to jointly solve the outlier detection and the final positioning problem.
- The third one directly estimates the location that has most likely caused the observed raw signal snapshot. The likelihood is optimised using a tailored branch-and-bound algorithm [2].



A location likelihood on a map

Web Application

- We implemented all algorithms in an open-source back-end of a public web application.
- Via the website, you can configure your receiver, upload raw data, and calculate tracks.



SnapperGPS on Loggerhead Sea Turtles

A nesting loggerhead sea turtle

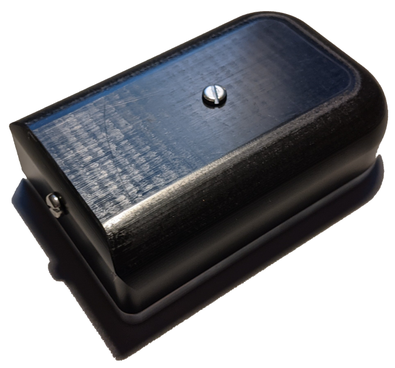
Attaching a tag to a loggerhead sea turtle

Loggerhead sea turtles (Caretta caretta)

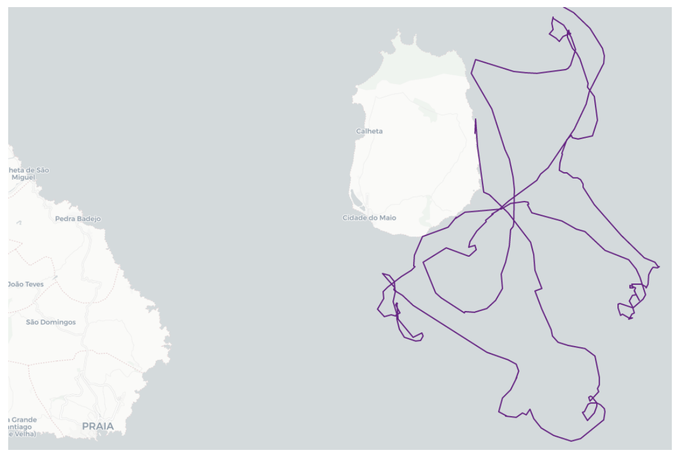
To test SnapperGPS under field conditions we organised a deployment on loggerhead sea turtles (Caretta caretta) on the island of Maio, Cape Verde with the Maio Biodiversity Foundation (FMB).

Loggerhead sea turtles spend most of their life in the ocean, but come up to the surface regularly to breathe. Every few years, mature females come to the beach to nest. They lay several clutches separated by 14 days [3]. This makes nesting loggerhead sea turtles a great deployment opportunity for SnapperGPS because

- Surfacing events present very short windows of opportunity for GNSS data capture which showcases a big advantage of snapshot GNSS;
- Nesting turtles on their first clutch predictably return to a nearby beach after 14 days which makes recapture possible with beach patrols;
- Turtle tags can be non-invasively glued to the carapace with epoxy and fibreglass matting.



SnapperGPS enclosure for turtles



Turtle track recorded by a recovered tag

Enclosure

For this turtle deployment, we designed waterproof cases inspired by enclosures used by the Arribada Initiative for their Horizon boards. The top is made from a thermoplastic which is screwed close with an aluminium plate. The enclosure measures 56 mm × 88 mm × 25 mm and weighs 190 g with the board and antenna. The tags were tested to be waterproof to 10 bar or 100 m.

Results

Due to the COVID-19 pandemic, this field work was delayed which resulted in deployments later in the nesting season. This meant that tagged turtles were more likely to be laying their last set of eggs for the season. Recovery rate was therefore lower than expected. The tags also had issues with detecting surfacing events. We were still able to recover several tags that recorded tracks. This is the first time researchers on Maio have been able to study internesting behaviour of loggerhead sea turtles in the area.

Conclusions

SnapperGPS is a **small**, **low-cost** and **low-power** wildlife tracking system. It comprises a purpose-built receiver and robust algorithms that are implemented in a cloud-based web application. It will soon be available to the public and the entire hardware and software stack will be made **open source** to encourage innovation.

We have demonstrated that SnapperGPS can be used in the field to track wildlife. In particular, SnapperGPS has been used to track nesting loggerhead sea turtles on the island of Maio in the 2021 nesting season.

References

[1] J. Beuchert and A. Rogers, *SnapperGPS: Algorithms for Energy-Efficient Low-Cost Location Estimation Using GNSS Signal Snapshots*, in Conference on Embedded Networked Sensor Systems, SenSys '21, Coimbra, Portugal, November 2021, ACM.

[2] P. Bissig, M. Eichelberger, and R. Wattenhofer, *Fast and robust GPS fix using one millisecond of data*, in Conference on Information Processing in Sensor Networks, IPSN '17, ACM, 2017, pp. 223–234.

[3] C. K. Dodd Jr, *Synopsis of the biological data on the loggerhead sea turtle caretta caretta (linnaeus 1758).*, Florida cooperative fish and wildlife research unit Gainesville, (1988).

[4] J. Liu, B. Priyantha, T. Hart, H. S. Ramos, A. A. F. Loureiro, and Q. Wang, *Energy efficient GPS sensing with cloud offloading*, in Conference on Embedded Network Sensor Systems, SenSys '12, Toronto, Ontario, Canada, 2012, ACM, p. 85–98.

SnapperGPS website