Poster Abstract: AquaMote - Ultra Low Power Sensor Tag for Animal Localization and Fine Motion Tracking

Eun Sun Lee[1], Jeya Vikranth Jeyakumar[1], Bharathan Balaji[1], Rory Wilson[2], Mani Srivastava[1]
[1]University of California, Los Angeles [2]Swansea University
{eunsunlee,vikranth94,bbalaji,mbs}@ucla.edu,r.p.wilson@swansea.ac.uk

ABSTRACT

Tagging animals with sensors is a powerful approach to acquire critical information about the behavioural ecology of free-living animals, which ultimately can provide data to inform best practice in conservation efforts. Sensor tags for such deployments need long lifetimes and incorporate multiple sensors, especially location because space use can contextualize behavior. The tag size needs to be minimal so as not to affect the activities of the animal. Aquatic animals in particular present challenges due to lack of wireless communication and water-proofing. Taking these points into consideration we have designed *Aquamote*: an ultra-low power, tiny sensor tag (20 x 29 mm^2) which integrates accelerometer, gyroscope, magnetometer, depth sensor, GPS and BLE. Our poster will showcase the performance of AquaMote and highlight our design decisions to reduce its size and power consumption.

CCS CONCEPTS

• **Computer systems organization → Embedded hardware**; *Sensors and actuators*;

KEYWORDS

Marine animals, underwater, sensor tags, AquaMote, GPS

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1 INTRODUCTION

Studying marine animals provides many insights on their behavior, ecosystem and the effect of weather and climate. Researchers often use sensor tags to monitor population of animals, track their location in the wild and understand their behavior [4] as it provides a much deeper understanding than direct observation or by using cameras. There are a few key aspects to designing animal tags. First, the tag needs to weigh less than 3% of the animal weight [3] so that it is comfortable. The number of species that can be studied

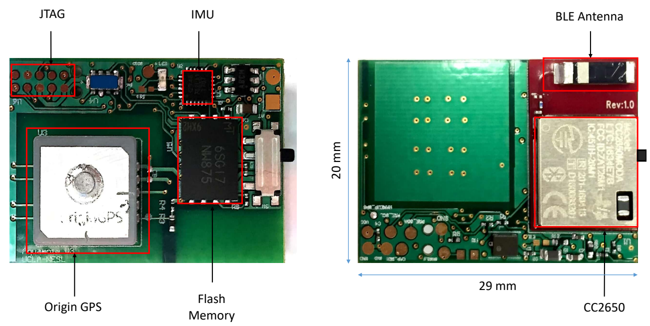

Figure 1: Aquamote Front and Back View

increases exponentially with decrease in size. Second, the tag needs to have a long life as replacing batteries may not be feasible in the wild. Marine life, in particular, presents a number of challenges. Radio does not work underwater which makes real time data transmission unsuitable. We need to log the data and transmit it when the animal surfaces or retrieve the tag when it goes to a known location. Location is a key information that reveals a lot about animal behavior, but GPS does not work underwater, thus accurate location information is difficult to obtain. GPS can be used in animals that surface frequently (e.g. penguins), but it takes a minimum of 30 seconds to obtain the first location fix.

Keeping these challenges in mind, we designed AquaMote, which pushes the state of the art with its compact design and ultra low power consumption. It includes GPS, BLE, depth and IMU sensors and is extensible to other sensors. It obtains location data by opportunistically logging GPS when the animal surfaces and uses IMU based dead reckoning for approximate localization. In the poster we will present the design trade-offs we made in the design of AquaMote and present its performance in terms of quality of service, longevity and power efficiency.

2 AQUAMOTE DESIGN

We use the TI CC2650 micro-controller as it has one of the lowest power consumption specification in the market. CC2650 has a Bluetooth Low Energy (BLE) radio and a low power sensor controller for continuous data collection. BLE is used for data retrieval as well as opportunistic communication with known anchors. We use the Origin Micro Hornet, a 10 x 10 mm^2 patch antenna GPS and a robust depth sensor that works up to 200m below sea level. We have added provisions to include analog and capacitive sensors as needed. We have carefully chosen the components in the board to support 1.8V supply voltage operation to increase power efficiency. The dimensions of our tag is 20mm x 29mm.

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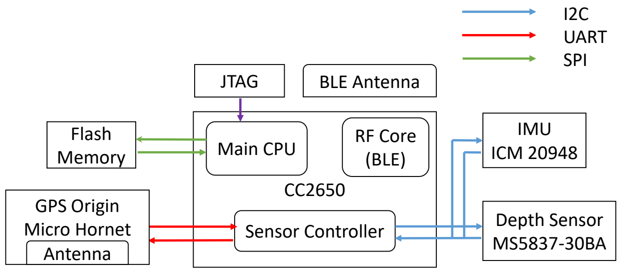

Figure 2: Design Architecture

2.1 Choice of Memory: Design Trade-offs

MicroSD memory card is the preferred option for logging data in embedded systems as it has a wide range of capacities. But a typical SD card operates at 3.3V and consumes >80 mA during a read/write cycle. The SD card power consumption is proportional to the amount of data being written to it and a high capacity SD card will require use of a larger battery, which in turn increases the size and weight of the sensor tag. Hence, we chose to use NAND Flash instead which consumes just 25 mA for read/write operations. Unlike SD cards, the NAND Flash chip is an SMD and helps in saving board space by 42.3%. But the trade-off is that the highest capacity for a NAND Flash which operates at 1.8V is only 256MB. Our marine biology collaborators plan to deploy the tag for 20 to 30 days, collecting sensor data at a maximum frequency of 40Hz. With binary formatted data, 256MB is sufficient. We have carefully chosen the components in AquaMote to be pin compatible for 3.3V operation. Hence, we can create tags with a 3.3V NAND Flash with the same design and increase capacity to 2GB if needed.

Note that the longevity of the tag is also decided by the size of the battery. With a 1.8V supply voltage, our longevity is limited by the smaller memory capacity of 256MB, and hence we can pick a smaller battery to reduce the size and weight of the tag. If a deployment needs larger lifetimes, we need to change supply voltage to 3.3V, and increase the memory capacity and battery size. The battery attaches to AquaMote on two copper pads, allows for these customizations.

2.2 GPS

GPS consumes 40mA in active mode because it needs to communicate with more than four satellites at 50 bits per second for an extended duration. Its battery drawing behavior is noticeable during the initial acquisition of the satellites navigation message. So whenever the animal is underwater, the GPS is switched to standby mode to avoid wasting power in searching for the signal. The data from the depth sensor is used to decide whether the animal is near the surface or underwater. The TTFF (Time To First Fix) is about 30 seconds to acquire the satellites. This means that the animal should spend at least 30 seconds on the surface of water to obtain a proper fix and record an accurate location. The animal surface time may range from a few seconds to several minutes depending on its behavior. To increase the location estimates, we need to reduce TTFF. We use the aided start by storing valid satellite almanac and ephemeris data in the AquaMote flash memory. The almanac data is valid for 180 days, which is longer than most deployments. The ephemeris data is valid for four hours and will be updated automatically with each location fix. The TTFF can be reduced to less than 6 seconds by this method. We configured the GPS to run in the low power mode when we detect it to be underwater, where it retains the satellite information in battery backed RAM with a low power consumption of 15uA. The stored satellite information can be used to obtain a fix within one second if the animal surfaces within 30 minutes of the first fix. The GPS can also be switched to standby mode whenever the animal is stationary for an extended period of time and this is decided based on the IMU sensor data.

2.3 Inertial Measurement Unit

Since GPS is available only at certain intervals IMU sensor data is the one which tells us about the actions and behavior of the animal. Accelerometer readings give us the movement of the animal in different directions and the gyroscope, magnetometer readings give us information on the orientation of the animal. The data is recorded at 40Hz and time synchronization of the data collected is very important to obtain the accurate timestamps while logging them. We use the timers available in CC2650 to maintain the local time in the module. The absolute time is obtained from the GPS readings and the time stamp is computed which is appended to the sensor data before writing to the memory. The time is corrected opportunistically with the absolute time from GPS to minimize drift errors and help in proper synchronization. We perform dead reckoning using the IMU data offline to predict the path taken by the animal in the absence of GPS location.

3 RELATED WORK

There are a few existing tags which uses Fastloc GPS that obtains a location fix within 100 ms but the accuracy is worse than GPS: from 100 meters to several kilometers. It also depends on power hungry Argos Satellites and has an expensive license [5]. Nanofix tag seems to be another option as it is very small (25 x 11 mm) but it collects only GPS data promising an accuracy of less than 10m and not much technical details are available [2]. The other existing tags which have integrated GPS, IMU and pressure are large and heavy compared to AquaMote [1].

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