IROTS - Illinois River Otter GPS Tracking System

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Introduction

The Illinois river otter tracking system project was enticing on many different fronts. We will be working on a project that will massively improve the tools researchers have to perform studies that involve animal tracking. The Illinois river otters are amazing creatures, extremely active, curious and playful. Working on a project that could improve our understanding of such enjoyable animals is in itself enough motivation to work on the project.

Picking up a project from last semester puts the added strain of trying to understand what previous students have done, but with the documentation style of the course, this should not be a daunting task. Also, having the previous research should give us a stepping stone towards the implementation of a field deployable tracking system.

The project is also attractive for the challenges we will face on the road to creating a viable product. We will have to work around stringent size restrictions, power availability, product life, and data accuracy. All these factors need to be taken into account in order for the tracking system to meet its expectations.

In order for this project to be a success, we must apply the majority of the ECE disciplines, from programming to power generation, communication to circuits, all this while taking into account the complex biological environment the otters are known to inhabit.

Objectives

The goal of the project is to create a device to track the Illinois river otter movement patterns. The device will need to be sub-cutaneous so as to minimize risk of injury to the otter, while ensuring the device is secured to the otter. This device will periodically acquire and store its GPS (global positioning system) coordinate. When the otter is within the download range of the base station, it will automatically relay the currently gathered information to the base station. The base station will have a USB interface for ease of data retrieval by the researchers.

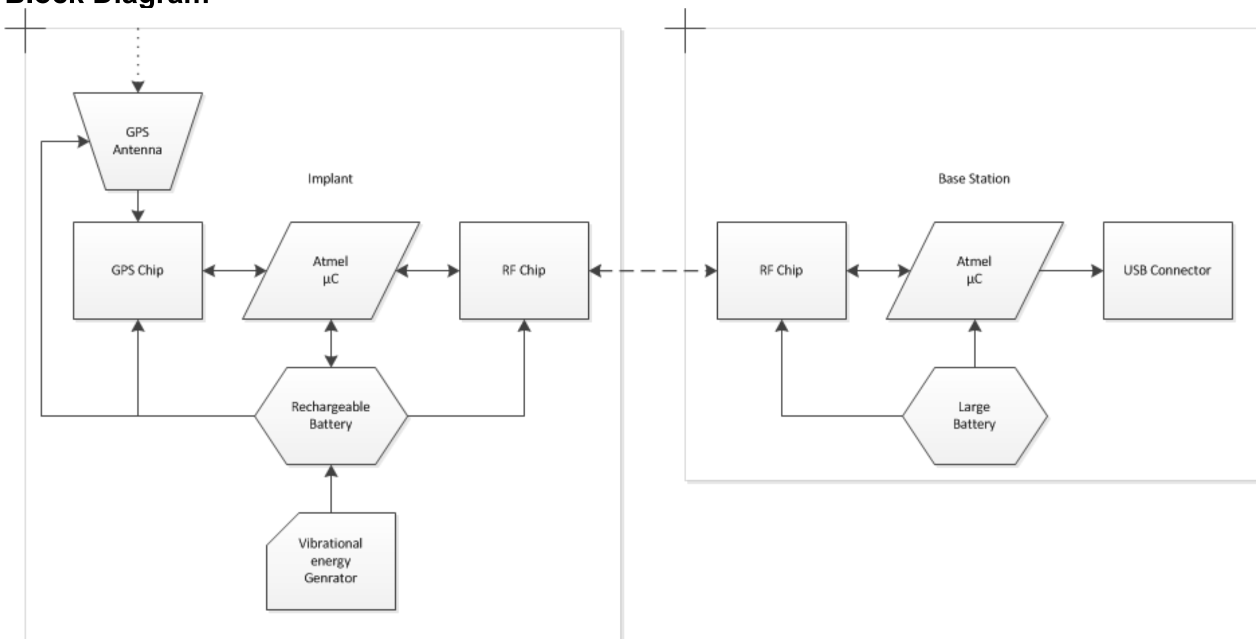
Benefits

- Alternative tracking system(for animals where collars or vests are impractical)
- Ease of use for researcher
    - location data easily downloaded from base station in text format
- Reduced risk to the animals
- High mapping definition with data point less than .25 miles apart
- Base station uses easily replaceable 9V batteries
- Make researchers jobs easier, give them new data acquisition methods

Features

- Base station operational for 6 weeks before battery change
- Stores latitude longitude altitude and time stamp information
- Implantable within the animal
- Automatic data transfer to base station
- Antenna is non-directional and active

Block Diagram



Note: μC ⇒Microcontroller

Note: RF ⇒Radio Frequency

Block Description

I. GPS Antenna

The Antenna should be able to pick up a low amplitude GPS signal. It should not be directional while remaining as small as possible.

II. GPS Chip

Using the antenna's filtered and amplified signals the GPS chip will decode the latitude, longitude, altitude and time readings and send an NMEA code to the microcontroller to be interpreted.

III. Inplant Microcontroller

The microcontroller will control the power control of the GPS chip, Antenna and RF chip. It will get NMEA data and store it in its flash memory until it is transmitted via the RF chip to the base station and verify the data transmitted.

IV. RF Chip

The RadioFrequency chips should be a transceiver that helps the implant microcontroller talk to the base station microcontroller.

V. Rechargeable Battery

The Rechargeable Battery supplies power to the implant electronics.

VI. Vibrational Energy Generator

This block should use kinetic/vibrational energy to charge the rechargeable battery.

VII. Base Station Microcontroller

This Microcontroller will get the data from Implant via the RF chip and store it. It will also be controlling the USB interface to allow for easy off-loading of the data.

VIII. USB Connector

This will be a place for the researcher to connect the USB stick and select an option to download the data.

IX. Large Battery

The battery for the base station will be something that can last for a long amount of time without needing to charge or change.

Requirements	Reasoning
I.GPS Antenna output -146 dBm GPS signal Non directional and active	Require to pick up GPS satellite signal while located in the subcutaneous tissue in the otter. The signal strength going to the GPS chip has to be at least -146 dBm
II. GPS Chip - 3 dimensional location as well as time information within 5 minutes of cold start UART communication standard	To save power we have limited the time for the satellite acquisition standard to save power as this is the highest power consumption component of the system.
III. Inplant Microcontroller - Store 150 GPS (2.7 kB), 2 UART interfaces at 9600 baud	Locations corresponding to 1 month of GPS data. Each GPS location will include latitude (4 bytes), longitude (4 bytes), time stamp (6 bytes), and altitude (4 bytes). The chip communicate at 2400 baud to initialize the GPS chip.
IV. RF transceiver Chip - 2400 Baud rate UART transmit range of 10 M	Requires UART communication to the Microcontroller at at least 2400 baud. We can assume that ten meters covers the otters home base.
V Rechargeable Battery - minimum of 15 mAh energy storage at 3.6V.	Has to generate more than 2.8 - 3.6 V for the GPS chip to function.
VI. Vibrational Energy generator - generate 30 mAh per day	30 mAh is a rough estimate of the daily power usage of the GPS. The battery requires at least its own voltage to charge.
VII. Base Station Microcontroller - minimum 60 kB storage. UART communication of 2400 Baud	The storage is for at least 4 month intervals of GPS data from 4 otters (48 kB) as well as enough space for the USB interface program. We can use 2400 Baud as the standard communication rate since there is not a huge amount of data to transfer

VIII. USB connector - 4 contact pins	USB standard requires 4 pins two for data transfer one for voltage and one ground
IX. Large Battery - greater than 5 V output power for 2 months	USB connector requires 5 V the microcontroller has a minimum of 2 months of data storage

Verification

I To test the GPS antenna's functionality within the subcutaneous tissue of the otter, we will place the chip antenna inside a similarly dense material and search for signals. This should give us an idea of the signal quality and interference to expect from the Otter skin cells. This will also act as a test of the GPS chip functionality and data storage utility (requirements **II** & **III**). We will also cycle the device through a few cold and warm starts to ensure our timing assumptions and power consumption values are accurate.

II We will download multiple stored GPS coordinates from the implant to the base station so as to test the range of the RF signal as well as the data storage capacity of the base station and implant microcontrollers.

III We will run all tests multiple times so as to run the battery through its paces to ensure our battery life expectations are accurate.

IV To test baud rate we will write a test program that communicates with the microcontroller at 2400 baud and look at the transmitted data for corruption. To test the storage requirement we will load 3 kB of data and then look at data for corruption.We will also download the data from the base station onto a laptop so as to check the USB interface functionality and the to ensure no corrupt data is being stored and transferred.

V Initial testing of the energy recovery system will include attaching oscilloscopes to the device while physically generating vibrations. We will then analyse the voltage and power outputs. Once we have determined initial power generation we will be able to estimate the size and the number of piezoelectric devices we would need to generate the amount of power required.We plan on straping the completed energy recovery system to a dog (or other pets) to test the functionality of the system as well as to confirm our estimates of the amount of power being generated by the implanted system.

In order to test the functionality of the completed device, we will need to put it through conditions similar to what it will be facing while implanted in the otter. The otters can stay underwater for up to eight minutes. GPS signals do not have a high penetration depth in water, thus we will test the signal strengths at different levels of submersion in a local pool to simulate a submerged otter, and determine the exact depth to which the otter can be tracked. The woods are another common hangout spot for the otter. However, the canopy caused by the tree tops in wooded areas do not allow for a high signal density, so we will be testing the GPS accuracy and signal strength in wooded gardens similar to the otter's habitat. This information will be useful so as to help the investigators determine the location of the otter where GPS coordinates could not be acquired by the implant.

After extensively testing the implant in outdoor conditions, we have to ensure that the RF communication between the implant and the base station is functional. We will be testing the download range and data accuracy so as to determine the optimal radius for data downloads to the station. We also have to test for possible sources of interference between the implant and the base station so as to help determine the optimal implantation location, as well as the optimal location for the base station.

Tolerance Analysis

The implants successful tracking and recording of the GPS locations are very heavily dependent on the Microcontrollers both at the base station and on the implant. Since we are using microcontrollers that are ‘pico-power’ the energy required to keep the chip running is very minimal. The microcontrollers should be functional even at voltages as low as 1.8 V and only require currents as low as 1-µA when in sleep mode. This gives the implant the ability to store data over a lengthy period of time when in power saver mode (not acquiring new GPS locations). At <3V we have used up ~75% of the power on the battery. If the battery drops below 3V then we will switch to power saver mode where the priority will be to get the data to the base-station.

Cost Analysis

Parts	Unit price ($)	Quantity (#)	Total cost ($)
Microcontroller	20	2	40
piezoelectric crystals	1	50	50
GPS chip	40	1	40
GPS antenna	30	1	30
USB female connector	5	1	5
Implant casing	20	1	20
Rechargeable battery	10	2	20
Large battery	10	2	20

PCB main board	30	1	30
TOTAL:			255

People	Hourly Rate	Hours per Week	Total
Bilal Gabula	$40*2.5	12	14400
Osaynmo Osarenkhoe	$40*2.5	12	14400
Gerard McCann	$40*2.5	12	14400

Project Total: $43425

Schedule (*Subject to change*)

Week	Task	Assignment
9/16	~~Proposal Design, schedule, choose GPS chip~~	Bilal
	~~Proposal Requirements/verification, Begin testing piezoelectrics viability~~	Osa
	~~Proposal introduction, PCB design requirements~~	Gerard
9/23	GPS chip testing code layout	Bilal
	Power system management requirements	Osa
	GPS antenna type, design review sign up	Gerard
9/30	Design Review(DR) simulation data, detailed schedule	Bilal
	DR power, ethical section, cost	Osa
	DR electrical design, test PCB sent to fab	Gerard
10/7	Begin implementing base station USB interface code	Bilal
	Finalize power system design begin implementation	Osa
	Research resin casing for implant begin final pcb design	Gerard
10/14	RF interface with μC	Bilal
	Solder components to test board	Osa
	Finish main PCB design/order	Gerard
10/21	Testing Rf communication, IPS (Individual progress) reports	Bilal
	Construct begin testing the base station, IPS reports	Osa
	Finalize protective resin for implantation in otter, IPS reports	Gerard

10/28	Mock up demo implant prep	Bilal
	Mock up demo base station prep	Osa
	Mock up presentation preparation	Gerard
11/4	Project overview/validation	Bilal
	Solder final board	Osa
	Order resin for encasing	Gerard
11/11	Field testing GPS on final board	Bilal
	Field test Rf offloading on final board	Osa
	Field test battery life on final board	Gerard
11/18	Thanksgiving break	
11/25	Mock Final demo	Bilal
	Final demo preparation/sign up	Osa
	Encase board for implantation,	Gerard
12/2	Final paper Intro/Design	Bilal
	Final paper, Verification costs	Osa
	Final paper conclusion	Gerard
12/9	Turn in final paper	Bilal
	Presentation organizer	Osa
	Checkout organizer	Gerard