OTTER FOOTPRINTS CAPTURING DEVICE

Project Proposal

ECE 445 Senior Design
Spring 2012

Names: Hoong Chin Ng, Sze Yin Foo, Sabrina Yan Ru Cheng
TA: Tom Galvin
Team: #9

Contents | Pages Number

I. Introduction

1. Title

Otter Footprints Capturing Device

This project is chosen to help create new technology in wildlife studies and will be conducted in collaboration with Illinois Natural History Survey to capture the footprints of otters frequenting a specific site on land in order to determine the number of individual otters.

2. Objectives

The goal of designing the Otter Footprints Capturing Device is to create new footprint-capturing technology in biological studies of wildlife especially endangered species such as the otters. The collaborating lab is currently conducting a detailed study on North American river otters existing in Illinois and wants to have a count of the number of individual otters frequenting a specific site in Homer, Illinois. The lab is currently trying to obtain otter footprints using clay boards but this yields poor results. Hence, the Otter Footprints Capturing Device will be designed to fit the purpose of capturing clear images of the footpads of the otters whenever they walk through the specific site. The images will later be collected by members of the lab to be sent to Indiana Police Forensics Lab for further processing in order to identify and maintain a footprint database for the individual otters. Thus, this project aims to contribute a whole-new device used in wildlife studies while assisting research work directed to preserve wildlife.

Functions:

This device will be hidden underground with a ground-level capturing surface. When the sensors detect the presence of an otter as it steps on the device, a camera beneath the transparent surface will capture an image of the footpad of the otter and save it in its memory card. This device will be able to operate without manual manipulation and charging up to four days.

Below is a sample footprint of an otter in actual size:

The red box outlines the part on the metacarpal pad of the river otter which will be magnified for obtaining the dot patterns used to distinguish individual otters.

Benefits:

- Whole-new footprint-capturing technology in the field of wildlife studies
- Operates independently without human manipulation or charging up to four days
- Provides clear and high quality images of otter footpads
- High durability since the surface is of scratch-resistant material and the body of device is protected underground

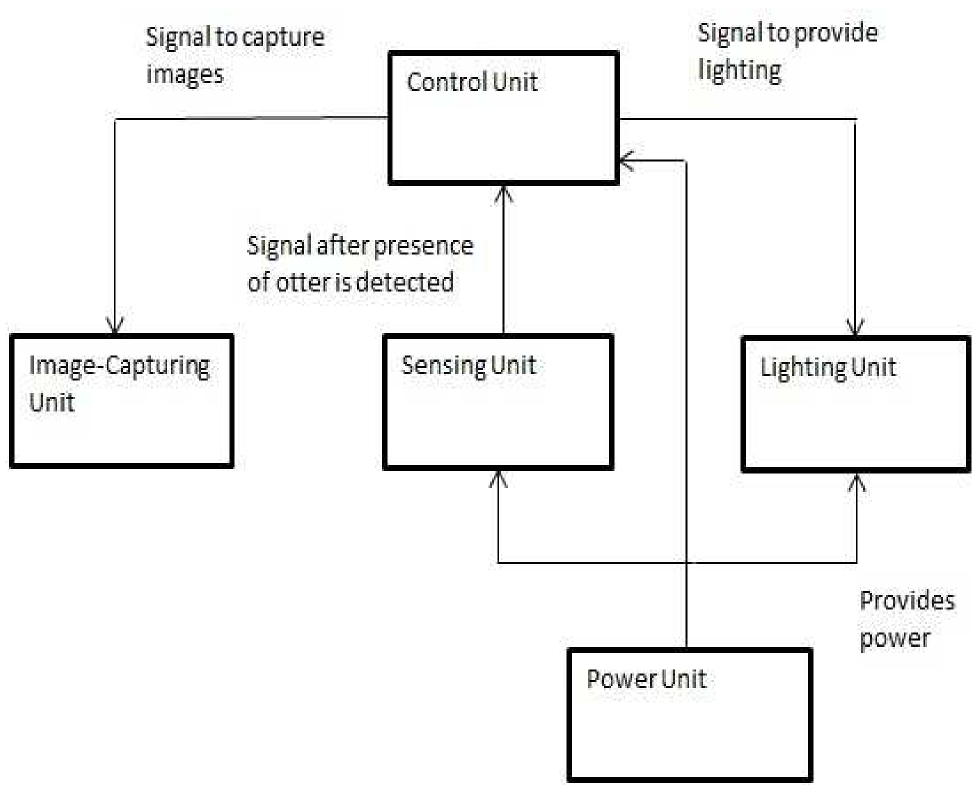
Features:

- An underground cube with a 24 x 18 inches ground-level capturing surface made of clear acrylic sheet

- White LEDs will be mounted along the sides of the capturing surface to provide adequate lighting for a high-quality image
- Motion and pressure sensors for detecting presence of otters whenever otters step on it
- The camera is triggered in USB mode through its wired shutter release trigger
- Inner circuitry (not including camera) will be powered by rechargeable batteries to provide power up to four days
- Able to provide high-quality images for identification purposes

II. Design

1. Block Diagram



2. Block Description

Sensing Unit

The sensing unit consists of motion sensors and pressure sensors. Any movements on the surface (an otter stepping onto it, remains on the surface, or leaving the surface) will trigger changes in the sensor outputs. The unit will then output these signals from sensors to the control unit.

Control Unit

The control unit is the brain of the device which analyzes the input signals from the sensing unit and decides the appropriate action from the inputs. It consists of an Arduino Uno microcontroller and a USB host shield. When an otter steps on the capturing surface, the microcontroller will decide to capture an image. If the otter remains or leave the surface, the microcontroller will not do anything. The USB host shield will be responsible for translating signals from the microcontroller to signals accepted by the camera through the USB port in Picture Transfer Protocol (PTP) mode. Through the USB host shield, the control unit will be able to control the shutter of the camera. When the device is capturing an image, the control unit will send a signal to the lighting unit to provide sufficient lighting in order to get a clear image.

Image-Capturing Unit

The image-capturing unit is the camera. It will be on standby when no otters are present. Once it receives the signal from the control unit through its USB port, the shutter of the camera will be released to take a picture of the otters' footpads on the capturing surface above. The images captured will be saved in a memory card. The camera will be powered by its own battery source. At the present stage of the project, the suggested camera model is Nikon D5100 DSLR with 18-55mm lens kit which is powered by Nikon EN-EL14 (1030mAh) batteries. It can take 660 shots in single-frame release mode when fully charged. As the device is designed for independent operation up to 4 days, 660 shots (165 shots per day) are sufficient to meet this particular requirement as otters are expected to frequent the site for only 3-4 hours in a whole day. For the camera optic, the 18-55mm lens kit has a maximum field of view of 76° at 18mm focal length which helps to reduce the depth of the enclosure to 2ft.

Lighting Unit

The lighting unit is consisted of white LEDs which will be mounted on the sides of the capturing surface. This setup enables the lights from LEDs to form guided waves within the transparent capturing surface. When the paw of the otter touches this surface, the footprint on the paw will stand out as the paw frustrates the total internal reflection of the guided waves. The LEDs will only light up when an image is to be captured to converse power. This means that the control unit triggers the image-capturing unit and the lighting unit simultaneously.

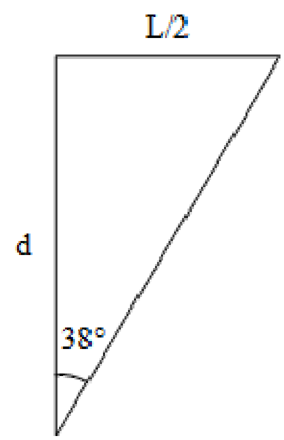
Power Unit

The power unit provides power to the control unit, the sensing unit, and the lighting unit. This will consist of rechargeable batteries. This device will use a total of six 1.2 V AA rechargeable batteries (2000mAh) connected in series which will give a voltage of 7.2 V. The most power-consuming part is the Arduino Uno microcontroller which needs an input voltage from 7-12V. Thus, 7.2 V is sufficient for driving the microcontroller and other parts.

Container

The container is a cube with 24 inches on each side. The dimensions are calculated based on the suggested model Nikon D5100 DSLR with 18mm focal length. On the top of the container is the transparent capturing surface with an area of 24 x 18 inches to accommodate the 4:3 aspect ratio of the camera image. This surface is made of an inch thick clear acrylic sheet that can support the weight of an adult. Now, the minimum depth can be calculated for the field of view of 76° by the camera optic and the capturing area of 24 x 18 inches as follow.

$$Diagonal\ length, L = \sqrt{24^2 + 18^2} = 30''$$



$$\tan 38° = \frac{L}{2d}$$

$$d = \frac{15''}{\tan 38^0} = 19.1991''$$

Hence, 24 inches deep enclosure is sufficient for the camera to capture the entire capturing surface.

3. Performance Requirement

- Response time of circuit < 0.5s

Response time is calculated from the moment the otter steps onto the capturing surface until the image is taken.

- Image sharpness in Modulation Transfer Function Scale (MTF-50) parameter scale > 500 line pairs/picture height

Below is a sample graph of the MTF-50 scale:

- Total images taken per fully-charged battery pack > 600 shots

Taking into account for variables such as the unpredictable occurrence of otters, the power usage of the camera will vary accordingly. Thus, based on the best battery performance of our reference camera model (Nikon D5100) which gives 660 shots with fully-charged batteries under ideal conditions, the device is estimated to be able to take > 600 shots with fully-charged batteries.

- Power supply of circuit > 4 days

The power unit has six 2000mAh batteries in series to drive the device without charging up to 4 days. The total power consumption of the circuit can only be calculated at the later part of the project when most of the designs have been experimented with and finalized, ie: the code for the microcontroller and USB host shield and the circuit arrangement of the lighting circuit.

III. Verification

1. Testing Procedures:

   i. Confirm that the camera (reference camera, NIKON D5100) will capture the 24 x 18 inches ground-level surface to ensure efficiency of device for the largest possible field of vision according to calculations. This can be done by measuring the real model accordingly to the pictures taken. Furthermore, verify that the acrylic sheet used is scratch-resistant and allows illumination to produce guided waves within the sheet for our purpose. A scratch test will be done using different materials such as plastic, metal and real otters on the site to ensure the acrylic sheet is scratch-resistant. Besides that, to test the illumination of the acrylic sheet, lights will be shined onto the edges and the sides of the sheet and images will be taken in the dark environment to ensure that the illumination is enough as guided wave to produce light source for a good quality picture with visible details such as the footprints.

   ii. Confirm that sensors which include motion sensor and pressure sensors produce accurate outputs so that the camera will be triggered to capture a picture under specific conditions. The sensors will trigger the camera when all the following conditions are fulfilled that indicates there is possible of new otter detected on the site. The conditions are:

      a) There are changes in motion of otters detected.

      b) There are changes in pressure which is the weight of otters detected.

   iii. Test the battery life of the whole system which includes the power supply unit and camera unit so that it would last for at least 4 days under all the conditions of lighting unit and sensor unit to capture high quality pictures. The system should also take at least 600 pictures. The power usage of the camera in USB mode should be tested as well to make sure the target of 600 shots can be achieved.

iv. Test the sharpness of the images. The pictures taken should be in high quality in order to detect the footprints of the otters and to be captured into the system of otter footprint. The sharpness of these images will be tested using the Modulation Transfer Function (MTF-50) parameter scale or similar parameter should be at least 400 line widths/picture heights. This can be tested using software such as Imatest or DXO Analyzer.

After fulfilling all the performance requirements, this project will be able to capture the footprints of the otter to help the Illinois Natural History Survey to identify each otter often found on site.

2. Tolerance Analysis:

The most important component of the project is to be able to capture high quality pictures in order to detect the footprints of the otter and to be captured and recognized into the system of otter footprint. The sharpness of these images will be tested using the Modulation Transfer Function (MTF-50) parameter scale or similar parameter should be at least 400 line widths/picture heights. This can be tested using software such as Imatest or DXO Analyzer. If the pictures captured do not fulfilled the image sharpness requirement, the fingerprints of the otter will not be able to be identified, and the whole project would not achieve any goal.

IV. Cost and Schedule

1. Cost Analysis

i. Labor:

Name	(Rate/hour)×(2.5)×(Total hours)	Total Price
Hoong Chin Ng	($30/hour)×(2.5)×(150 hours)	$11,250
Sabrina Cheng	($30/hour)×(2.5)×(150 hours)	$11,250
Sze Yin Foo	($30/hour)×(2.5)×(150 hours)	$11,250
Labor Total :		**$33,750**

ii. Parts:

Part Name	Quantity	Price/Unit	Total Price
Arduino UNO Microcontroller	1	$30	$30.00
USB Host Shield	1	$25	$25.00
Nikon D5100 Camera & lens	1	$600	$600.00
1” Polycarbonate Plastic (2ft×2ft)	1	$21	$21.00
Container (2ft×2ft×2ft)	1	$50	$50.00
Pressure Sensor	4	$12	$48.00
Motion Sensor	1	$15	$15.00
LED	20	$0.87	$17.40
6 Battery Pack 1.2V and Charger	1	$27	$27.00
Parts Total :			**$833.40**

iii. **Grand Total** = Labor + Parts
= $33,750 + $833.40
= $34,583.40

2. Schedule

Week	Date	Tasks	Team Member
1	2/6	Compilation and submission of proposal	Hoong Chin Ng
		Introduction and design proposal	Sabrina Cheng
		Verification testing, cost and schedule of proposal	Sze Yin Foo
2	2/13	Sign-up for Design Review and research on camera	Hoong Chin Ng
		Research on microcontroller and power supply	Sabrina Cheng
		Research on pressure and motion sensors	Sze Yin Foo

3	2/20	Finalize and present the Design Review	Hoong Chin Ng
		Progress discussion with Samantha	Sabrina Cheng
		Order parts	Sze Yin Foo
4	2/27	Write code for camera	Hoong Chin Ng
		Design the lighting unit	Sabrina Cheng
		Implement and test the pressure sensor	Sze Yin Foo
5	3/5	Write code for microcontroller	Hoong Chin Ng
		Design the power supply unit	Sabrina Cheng
		Implement and test the motion sensor	Sze Yin Foo
6	3/12	Combine all parts of the design	Hoong Chin Ng
		Testing of the power supply unit	Sabrina Cheng
		Design the plastic surface and container	Sze Yin Foo
7	3/19	SPRING BREAK	
8	3/26	Mock-up Demos	Hoong Chin Ng
		Sign-up for Mock-up Presentation	Sabrina Cheng
		Prepare for Mock-up Presentation	Sze Yin Foo
9	4/2	Assemble the real model on site	Hoong Chin Ng
		Testing model on site	Sabrina Cheng
		Compilation and analysis of data	Sze Yin Foo
10	4/9	Testing and debugging of the model	Hoong Chin Ng
		Discussion with Samantha	Sabrina Cheng
		Compile information for Final Report	Sze Yin Foo
11	4/16	Sign-up for Demo	Hoong Chin Ng
		Sign-up for Presentation	Sabrina Cheng
		Prepare for Demo	Sze Yin Foo
12	4/23	Prepare for Presentation	Hoong Chin Ng
		Demo	Sabrina Cheng
		Finish first draft of Final Report	Sze Yin Foo
13	4/30	Presentation	Hoong Chin Ng
		Finish the Final Report	Sabrina Cheng
		Finalize and submit the Final Report	Sze Yin Foo