Development of a indigeneous Wildlife Camera Trap

B.Tech project by

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Certificate

This is certify that the following report titled "Wildlife Camera Trap", submitted by Sahitesh Kumar Reddypelly, 2013EE10490 and Matta Joshua Shushan Roy, 2013EE10471 in partial fulfilment of the academic requirements of the course ELD455 BTech Project Part 2 represents bonafide work done under my supervision. It has not been submitted elsewhere to the best of my knowledge.

Subrat Kar
28 Apr 2017

Prof.Subrat Kar
Dept of Electrical Engineering &
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Chapter 1

Introduction

1.1 Motivation

Every year wild life programs collect data from hunters,trappers and outdoor enthusiasts on wild life. Such public surveys are done based on the necessity. For example, on April 12, 2016 there was a news in Hindustan Times that there were many reports of leopard deaths in the area. The Government of Haryana assigned the counting task to Wildlife Institute of India, Dehradun way before the incident. For this task, they took help of all the volunteers they can get and individually took photos of all the animals in the Area. The results were supposed to be published in a month according to the report. Proposal for this task was made in November 2014. The survey is still going on. To avoid the whole arduous job we can use camera traps or deer cameras to calculate the populace more efficiently and accurately. There are many camera traps available in the market but none are specific for the Indian conditions and most are too costly. Our objective is to design a trail camera which can help us with the survey and tolerant to harsh Indian environment.[5]

1.2 Literature survey

The best trail cameras are not always the expensive ones. It mostly depends on the requirements . For example, if the camera is in a place where it takes thousands of photographs a day, trigger speed of the camera does not matter. But, if the camera rarely takes a photograph in the area used, the same trigger speed will become highly relevant because we don't want to miss a single photograph that way. Recovery speed which apparently go unnoticed is important as we may lose a lot of photographs during this time. This gives us an idea of consumer expectations from trial camera. [12]

There are many competing wild-game cameras currently available in the market. Most of these cameras are used for hunting purposes. Each provides different specifications for the camera and client service. These different specifications are given in Table 1.1

We analyzed different types of Cameras Available in market. This was done in order to evolve the best set of design specifications while retaining customer loyalty, which is strongly brand specific. Thus, if we were finally able to say that our trail camera was 100% Bushell compatible, we would have a strong chance of attracting loyal Bushnell customers.

Moultrie panoramic cameras have a increased field of view. They have a rotating lens which move takes images of animals in panoramic view. If the Motion sensor is triggered, it takes burst shots which gives the same

Photo						
Name	Reconix Hyperfire SC950	Moultrie Panaramic 150 Game Cam	Browning Strike Force HD lite	Stealth Cam G30	Bushnell Trophy Camera-Wireless	Our Camera Trap
Vendor	trialcampro.com	moultriefeeders.com	shop.browningtrailcamers.com	amazon.com	amazon.com	-
Cost	$650	$239.99	$169.99	$120	$368.96	103$ approx.
IR flash	100ft	100ft	100ft	80ft	60ft	60ft
Camera's MP	3.1	0.5/2/4/8	10	2/4/8	8	5
Time Lapse	1,5,10,30	-	1,5,10,30,60	-	-	-
Memory	32GB	32GB	32GB	32GB	-	16GB
PIR settings	low/med/high	-	-	-	low/med/high	low/med/high
Battery	12AA	6 c-cell	-	8AA	4-12AA	10400mAH powerbank
FOV	42°	150°	-	-	-	45°
Detection	70ft	45ft	55ft	50ft	40ft	40 ft
Trigger speed	1s	1s	0.4s	0.5s	-	-
Video	No	No	720p HD	720p HD	720p HD	-
GPS tag	No	No	No	Yes	Yes	Yes
Wireless	No	No	No	No	Yes	Yes

Table 1.1: Specifications of different commercially available cameras [6]

animal in three different angles. There is a delay of 1.3 seconds between the image capture. Specialty of this particular product is 150 degree field of view. Browning strike force HD lite has extra feature of TV out. We can view the images by connecting the device to a Smart TV.

Reconix Hyperfire has a lot of customizations. We can adjust flash setting, PIR setting ,time lapse and start/stop time . It is the most expensive product on our list. Bushnell is the most widely successful product for a long time now. Difference in this product is that they provide a SIM with a data plan. They access the images from the camera, store it in their data base and charge the customer for downloading images from their cameras. They also provide customizable battery compartment. We can use 4-12 AA batteries. With 12 AA batteries, camera can run upto 30 days or 700 photos. Trigger speed is 1 second. So, if an animal sits in front of camera for say 5 hours, the battery will be dead. So, battery is dependent completely on the number of photos taken. When we are talking about economy, Stealth cam is the best. It has become a best seller recently. It costs only one twenty dollars with import charges it would costs around ten thousand rupees in India compared to Bushnell which would cost twenty five thousand rupees in India.

1.3 Past work – what have others done so far

Trail cameras started back in early nineteenth century. It started by using trip wire sensor. When an animal triggers a wire, a boxed camera takes a photograph. All the progress today has happened in the past four decades. A great improvement in trail cam direction was when a 35 mm camera first came into use in 1950. It could take 36 shots of negatives. This is a film type camera. Now a days, we only use digital cameras. There are three broard tasks a trail camera performs. First is motion triggering which serves as an input for the second task which is taking a photograph. Third is storage and recovery of the photographs taken.

Initially, people used mechanical trigger for detecting motion. As in earlier forms of trail camera a trip wire is used to detect animal presence. But, the need for not spooking the animals for hunting purposes initially and later for observation has increased. People started using electronic motion detection. There are many types of electronic motion trigger. These are all sensor based technologies. They are Infrared(passive and active), Optical sensors, Radio Frequency energy, Sound sensors, Vibration sensors and Magnetic sensors. Infrared sensors detect heat signatures. It gets tripped when there is a rapid change in heat signature in its field of view. This makes it perfect for home surveillance since it can identify any intruders on private property. There are also microwave based sensors. These are expensive but they cover larger area. Sound wave sensors works on the principle of reflection of Ultraviolet waves. Tomographic sensors are based on radio waves which can detect an object through walls.

There are many factors which comes into play when taking a photograph. Lighting is one of them. Earlier people used to depend on the natural light, sun. To take images of object even during night, we started using artificial light. A major break through in a creating artificial lighting for photography is Electronic Flash. This increased the intensity of light and shorten duration. We can even sense the distance to the object using an infrared sensor and adjust the aperture, flash intensity automatically.This is called auto-flash. Deer camera specifications are pretty clear. We want a camera which does not in any way spook the animal. Most animals have their eye sight in the visible spectrum. If we use a flash in the infrared region, we can avoid being detected. Factors such as field of view, time lapse, shutter speed, camera resolution, lens play a crucial role in taking a photograph which we will discuss later.

Main uses of camera traps is observation and research, provide evidence for management and policy decisions, regular count of different species in an area, behavioral and activity pattern, tracing the animal, survey endangered species, population change data, effects of forest fires and deforestation, identifying poachers and many other. We have done a market analysis on the variety of trail cameras available. Some of the companies with best trail cameras in the market are Bushnell, Moultriefeeders, Stealth cam, Browningtrialcam, Reconyx. All of them use Passive Infrared sensors(PIR) for motion triggering. Flash used is of two types No glow flash and low-glow flash.

An interesting camera trap based idea was proposed by ZSL recently. Zoological society of London(ZSL) has developed a new generation technology called Instant Detect. Main function of Instant detect is to identify poachers. It is a camera trap system which can instantly send images taken using satellite technology any where in the world. This can be used to notify rangers in the area a warning to avoid poaching. Recently, BBC were banned in India till 2020 from any wild life photography. BBC did a documentary on Anti poaching laws in India which says that a ranger have shoot on site right against poachers. Though this is true, the reason government approved this is because poachers have heavy fire power because they come prepared for a Rhinoceros. So, to act first and shoot to kill is the only advantage they have. In 2015, more than 20 poachers were killed. Camera traps can avoid these many deaths when used properly. Using drones can also be an alternative, but camera traps can provide a permanent solution. [1]

1.4 What are the outstanding issues and problems we will tackle

Camera should be able to identify an animal at 50ft distance and operate both during day and night. Should take pictures on motion triggering and not to spook animals in the forest which could lead to damage for our product. As this is a wild life camera trap, it should be camouflaged for protection from animals.The time, date and location of the image taken should be recorded on the image. As this device is mostly based in forest, power optimization (prolonged battery life) should be given highest priority.There should be a way to communicate with the device to download images.The Camera should be tolerant to all environmental conditions. Some problems with trial cameras trending in the market are no proper data transfer method, specific to Indian settings. More economic because the existing cameras have to be imported which increases their price.

1.5 Why do we want to tackle these problems? Why only these problems?

Necessity is the mother of invention. Surveys are done regularly by Researchers and wild life organizations . These are essential to keep track of how human beings are effecting the ecological balance. India is a country with rich wild life. With increasing awareness in technology, there is need for us to aid in this area of research. Cameras with flash are seen as threat by animals. There is a high probability that animals like monkeys, leopards, tigers breaks the device. Camera traps are put deep within the forest. It would be best if the need for visiting each deer cam is as less as possible. For this, battery life should be optimized.

1.6 Organization of Thesis

In Chapter 1, we introduce you to the trail camera and why they are needed. Then we talk about the issues we address through this project and the reason for addressing those issues. In Chapter 2, shows the methods and the ways in which we approached different tasks and the tools that we used to achieve it. In Chapter 3, we describe the implementation of the design and summarize the experimental results. Chapter 4 deals with the communication interface design and protocols by which we control and retrieve images from the device. Finally in Chapter 5, we summarize the results obtained so far and describe the future plan of action.

Chapter 2

Methodology, Approach and Tools

2.1 Initial Approach

The basic Approach is as given in the Fig.2-1. We have a storage device at home, say a laptop or Android. We should be able to communicate with the device and the device should take photographs of animals in forest on its own. The best way to go about this will be to find what all interesting existing ideas are preferred by consumers. Only then can we improve upon the product reducing the unnecessary technology based on our requirements. We start with analysis of the market.

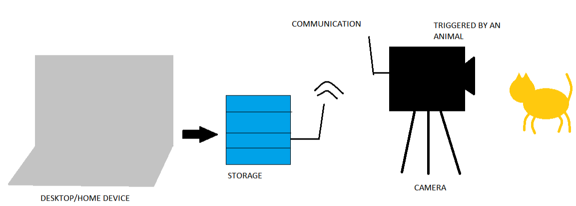


Figure 2-1: Initial approach

2.2 Approach

Let us consider a camera. Field of view is in general equal to 48 degree. What if we want to achieve a 150 deg field of view ? As we can see in the Fig.2-2 we can place three cameras at an angle as shown. Images taken can give panoramic view of the image. Other way would be to move the lens along a slider while taking the image as shown in the Fig.2-3. Do we really need a field of view of 150 degree ? It can be useful if our sample set is low. In a forest, image of animal in one angle is more than enough. Even if the requirement is more, we can always use multiple camera traps placed adjacent to each other. So, FOV of 48 deg is enough for the product.

Too many customizable settings confuses the customer and it is meant for a professional photographer who is just waiting for a shot for years. Our objective is a general purpose camera. So, fixed PIR and flash settings with date stamp on the image is essential. GPS tag like in the stealth cam can only be used is the area has some network connectivity which is rare in deep forests in India.

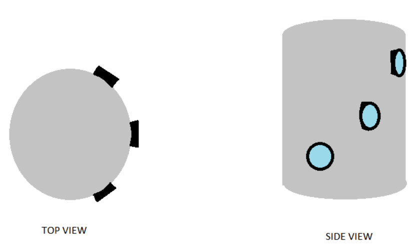


Figure 2-2: Lens placement

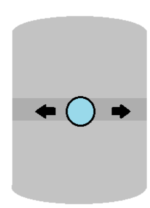


Figure 2-3: Movable lens

2.3 Requirements

Some of the primary goals for the camera are:

- Camera should be able to identify an animal at 50ft distance
- It should be able to operate both during day and night
- Should be able to take pictures on motion triggering
- The design should be so as to not to spook animals in the forest which could lead to damage for our product
- As this is a wild life camera trap, it should be camouflaged for protection from animals.
- The time, date and location of the image taken should be recorded on the image
- As this device is mostly based in forest, power optimization (prolonged battery life) should be given highest priority.
- There should be a way to communicate with the device to download images
- The Camera should be tolerant to all environmental conditions

2.4 Essential tools

We use – Raspberry Pi 3 Model B, 5MP NoIR Camera, 10400mAh power bank, 36 IR led's angular array, 16GB memory card, Buck boost converter, IRFZ44N Mosfets, vsftpd package for FTP server, Android Studio for android application, Apache Commons Net for FTP client to satisfy our objectives one by one systematically.

2.4.1 Camera

Observation of animals is one of the primary objectives. If we are able to differentiate animals among the same species, counting, sampling the population, tracing and many other research areas open up. How to identify a specific animal? Animals can be distinguished based on their size, deformities and some unique features to the specific species. To decide on the resolution see the following images 3D (see fig:2-4) and its corresponding side 2D (see fig:2-5).

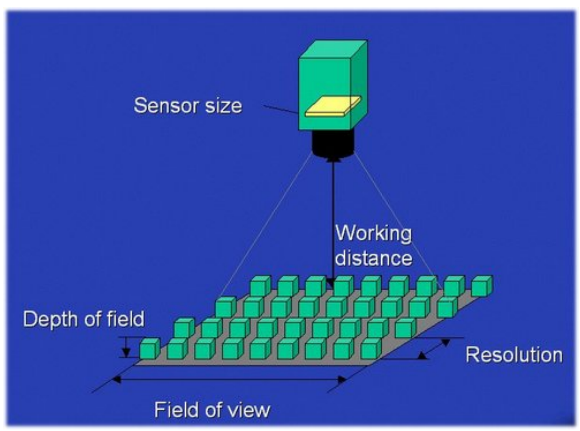


Figure 2-4: Depth of field,Resolution and Working distance

Source: http://digital.ni.com/public.nsf/allkb/1BD65CB07933DE0186258087006FEBEA

Sensor resolution is the number of pixels in the image. Which is also equal to image resolution. We have to calculate minimum possible resolution. For accurate measurements, the distance between smallest features should be minimum two pixels. Consider the field of view image2-4 in two

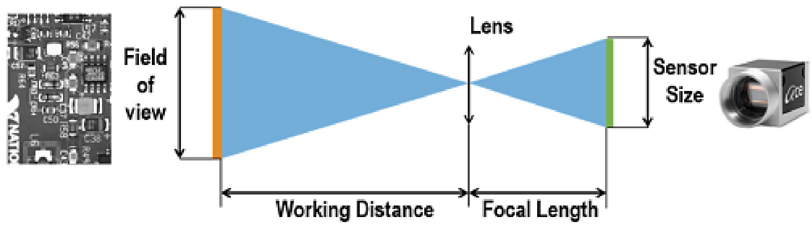


Figure 2-5: Side view of the above image

Source: http://digital.ni.com/public.nsf/allkb/1BD65CB07933DE0186258087006FEBEA

dimensional format and take a specific animal identification procedure.

Most of the animals have length to height ratio as 2:1. Photograph screen will mostly be empty. Choosing an Aspect ratio we could optimize the photograph to cover only the animal. As 2:1 aspect ratio is not available in market, closest is 16:9 . We have to select an animal. Each tiger has unique stripe pattern. So, we will try to identify the Tiger for the following discussion. Now, to distinguish between two stripes on a pattern the inter-stripe spacing should be equal to 2 pixels on a camera. If we decide on width, height can be calculated based on our fixed aspect ratio we decided earlier.

Maximum distance between tiger and the camera $= 70ft$

Field of view of each camera can go upto $= 48^o$

FOV from fig:2-4 $= 2 * 70\tan(24^o)$

Number of stripes on Tiger $= 100\ approx.$

Consider only black or only white for smallest feature $= 50 approx.$

Excluding head and tail stripes $= 40$

smallest feature $=$ tiger size/number of stripes

number of pixels for width $=$ FOV/ smallest feature number of pixels $= 2 \times (80 \times 0.466 \times 70/8.33ft) = 600(approx.)$

This value comes around to 600 pixels. Closest pixel resolution available is 640 pixel. As, we decide on the aspect ratio as 16:9. Number of pixel in height will be 360 pixels. Therefore the resolution we decided is 640x360p [7]. Taking 16 bit resolution for each pixel gives around 3.6 Mega pixel camera requirement. So, for better results we went with a 5 MP "No-IR" Camera.

It is essential for our camera to be “No IR”. Normal cameras have an IR filter to eliminate any IR rays present. This is to reduce noise and give us a photograph more suitable to human eye sight. In this No IR camera, that filter is not present gives us opportunity to capture night vision images.Images taken during night are all black and white.

To take pictures of animals even during night, we need a night vision camera. But that will not be enough since there is little IR radiation output which will not make an effect on the camera. So we have introduced an IR flash around the camera so that we can illuminate the animal before taking the picture.

2.4.2 Infrared flash

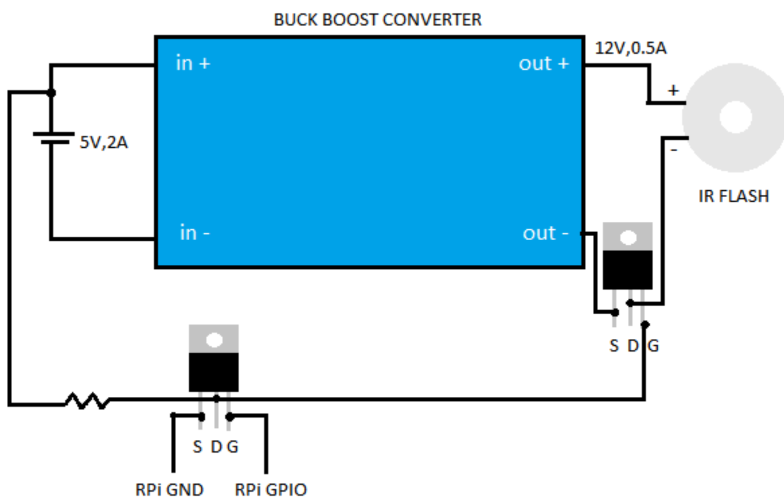
We discussed in the introduction how flash photography has advanced. Electronic flash makes it possible for us to instantly switch on the flash only when needed. Flash consumes a lot of power.Even if we don’t spook the animals with flash, We can afford to switch it on for more time than necessary. Infrared flash are usually of two types – ‘no glow’ flash and 'low glow' infrared flash. No glow uses 940nm IR leds for flash purposes whereas low glow shows a slight red glow. No glow IR flash is effective in not spooking the animals but gives lesser light and is also costly. We choose to go with 'low glow' because images are a lot clear during night. We will face problems only with animals like deers, weasel family and otters.

Considering a closed room. We want to light about a room of area. About 100 lux of light is needed to view an animal at 40 feet. So, area of illumination should be 1200 square feet assuming field of view for our camera as 50 degree. In lumens, we need 11148.3 lumen of illumination.

This can be achieved by a single high power IR led or an array of low power IR led's. We choose to go with array of low power led's since the power requirement for both is same, if one of the leds is malfunctioning remaining still continue to work and the current requirement for high power is too high (about 1.5 Amperes). Each small LED can provide 300 lumen of light. So, 37 led's are needed for operation. We used an array of 36 led's on an angular ring which fits right around the position of camera. Each led works in the range of 12V,10-20 mA current. This sums upto 0.6 A max current. We will discuss about battery separately but we are using a power bank to power the Raspberry pi.

Powering the Infrared flash

We had to make a dot matrix board as shown in the figure2-6 for powering the IR flash.



is

Figure 2-6: Switching module for IR flash

This is a challenging task as the only source of power is a power bank which has a second slot with 5V, 1A specification. We need at least 12 Volts for operation of IR LED array. Best solution is to use a buck boost converter to increase the output voltage to 12 Volts. We have to be able to control the Infrared flash using Rpi control signal. We can use MOSFET as a switch. First, we thought of using BJT, but BJT draws base current in ON state. If this current exceed 16 mA, rpi will be destroyed. So, it is better to be safe. The next challenge was most MOSFET's operate at 5V range. We had to find a MOSFET which responds to the 3.3 vsignal from Rpi. We choose IRFZ44N as the Mosfet. As Vgs increases, I_D increases. Maximum voltage across Load(IR flash) is observed to be 4 Volt. As Vg increases, Voltage across IR flash . We can change the MOSFET, 2N2222 will work in the gate voltage 3.3 Volt range but it costs Rs.360 per one piece as it should be imported. Best way we thought is to use a cascade of 2 MOSFET's. One is used for triggering the second Mosfet and the other to operate the IR flash. 5 V external voltage required is supplied from the power bank.

2.4.3 Motion Triggering

We discussed the motion triggering in Introduction, it is one of the basic function for camera trap. Motion triggering as evolved from mechanical to various electronic based which do not disturb the daily life of animals in forest. We will briefly go through some of the possible methods.

- **Laser trip wire** sensor uses lasers to detect motion. Laser is placed with the device and a photo detector away from device. Let's say we want a range of 40feet. detector is placed 40 feet away from device. As they are cheap, we can use as many as we want. This is a viable option but is not eye-safe to animals. Also, it detects a log or any kind of hindrance placed between. Our camera should work for 50 ft distance and field of view of 60 deg circuit contains a photo detector. We want to confine ourselves to a single box enclosure and detect only animals if possible

- **Ultrasonic sensor** is based on reflection of sound by an opaque object. It measures the time interval between incident and reflected ultrasonics to determine position of object. Drawback is that it is not specific to animals, any non living thing can trigger it.

- **Passive Infrared sensor(PIR)** measures the heat differences between 2 detectors on it, when it crosses a certain threshold it gets triggered. So, this detects presence of a living organism, can work day and night, cheap, threshold can be adjusted based on the environment. We choose this as the motion triggering detector for our project. There are other motion sensors available in the market but are expensive or most do not agree with our required specification.

I also discussed micro wave sensor, tomography sensor. These are expensive. We can also see in the market analysis that PIR most widely used motion trigger method in camera traps.

2.4.4 Micro controller

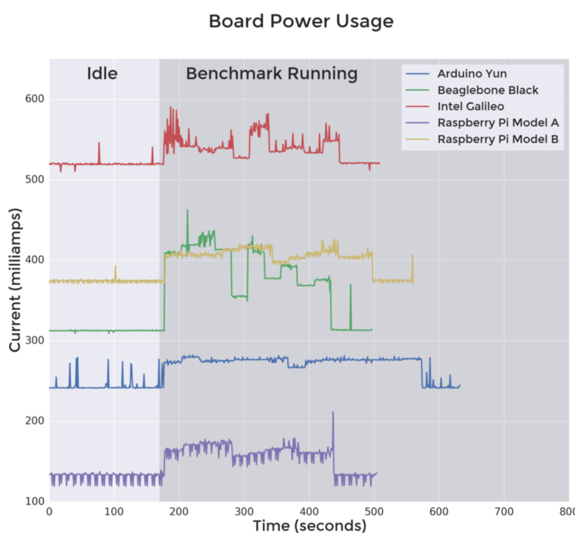


Figure 2-7: Comparison of Power Usage

Source: https://learn.adafruit.com/embedded-linux-board-comparison/power-usage

We need to execute operations like taking the picture when pir is triggered, storing those images according to time and date and transferring those images to other devices. These operations can only be executed by a micro controller. Power usage of some of the micro controllers are measured based on amount of current drawn using nbench benchmark tool and the results are shown in the figure2-7. This shows that the Average power budget for Arduino Yun and Beaglebone are less than Raspberry pi. Average power demand by Raspberry pi 3 is 350 mA. The cost of individual micro controllers comes down to this, Arduino Yun-Rs.5,500 Beagle bone-Rs.4,600 and Rpi-Rs.2,980. Rpi though consumes more power we could use it and manage power to increase efficiency. Other micro controllers such as Parallel board, and Chip also have Wifi, bluetooth network as required but no input/output pins for operation of flash and PIR. Aruino based Edison kit could be useful because it can provide voltages in the range 7-12 volts to run IR flash directly. It is expensive and the processor is slower 500 MHz compared to 1.2 GHz for Raspberry. Arduino has very minimal functionality and requires too many supplementary equipment like Wifi dongle, bluetooth module which would increase the cost to Rs.3,400 including modules and could work as an alternative. Raspberry pi has all the essential components in-built and has wide functionality. It is like a small computer. We can easily install Raspbian OS which has linux kernel.We choose Raspberry pi Model B Version 3.

2.4.5 Battery

Values of power consumption is from pidramble.com site. Raspberry pi consumes 450mA(2.3 W) average power with Wifi and Bluetooth on and

1.2 W in idle state. It consumes about 480 mA on average and a maximum of 730mA(3.7W) at 400 % CPU which is high stress state usually never happens. By turning off the HDMI port and on-board led's we can reduce the load by 50 mA and power by approximately 250mW.

We thought of an idea in the previous semester of making an array of PIR sensors and using them to switch rpi on/off. We made the array but power management is quite difficult. We cannot control the camera interface from command prompt. So, camera will always be on. There is a method of power management which is using a sleepy pi, an on-board add on for rpi. But, this does not take control of individual interfaces and GPIO pins but instead switches rpi off based on a input signal. We could still use PIR sensor as input to switch it off or back on but time for booting a pi ranges from 10-15 seconds. By the time we boot it, animal would have been already gone. We can only achieve sleep state if we switch off the code and camera interface. As it is not possible, we can instead optimize the code to save power. We have created a hotspot on rpi and can check the available wifi to turn on wifi at regular intervals. It only stays on if it detects an available.

Average load requirement is 450mA by rpi(350mA+ 100mA extra for camera+program to run). Time our device can work without charge varies with the number of photos taken as IR flash is dependent on photograph capture. Flash stays on for 1.5 seconds everytime it takes a photo. Flash consumes 500 mA for the time it is switched on. On an average if the camera takes 400 images per hour, it will work for 12 hrs given we are using 10400 mAH.

Chapter 3

Implementation of the Design and Experimental Results

3.1 Setting up Raspberry Pi

3.1.1 Installing OS for Raspberry Pi

We used Rpi 3 model B 64-bit Quad core. It has a CPU 1.2 GHz, Quad core ARMv8. It has 4x 2.0 USB ports, 1x HDMI, 1Gb RAM, 40 pin GPIO header and a memory card slot. For Networking, 802.11n Wireless LAN and Bluetooth 4.0 are in-built. Raspberry Pi(rpi) can be accessed through a laptop, Desktop or any device remotely. But, first we have to start with installation of Operating System(OS). Many distributors provide a SD card with NOOBS pre-installed in the kit. In case, we buy rpi as a single unit then we have to buy a micro SD card separately.Format the SD card in FAT32 format to avoid some errors in installation. Now, for beginners it is best to download NOOBS OS setup from the raspberrypi.org site and extract the OS directly on to the SD card. We are essentially making a bootable sd card. This can be accomplished by third party applications, extracting and copy pasting the files on SD card.

3.1.2 Setting up for the first time

For the first time a monitor and mouse is compulsory for installation. Plug in the monitor and mouse and power the raspberry pi. Note that 5v,2.5A is the power supply needed for operation. We get an adopter in the kit which can be used to boot rpi. Once started a list of OS is displayed where we select raspbian OS and install it. Once installation is complete you are logged in automatically. It is useful to remember that your default login is pi and password is raspberry. If a Graphical User Interface is displayed your installation is a success. If a mouse, keyboard and monitor is available there is no need to do anything further. skip next three paragraphs.

3.1.3 Network settings for Internet connectivity and remote access

To access our rpi through android and laptop anytime anywhere, we have to do the following. Plug in a keyboard. For communicating between rpi and any other device, they should both be in the same network and we need the ip address of rpi. At home, connect to your home router and check the rpi ip address by hovering over the Ethernet/Wifi connection on GUI of rpi. Alternatively, open termianl and type ipconfig command to get the respective ip address. Note that in universities like IIT Delhi every time you get connected to a different router, rpi is assigned a different ip address. First, we thought of using a static ip address to overcome this. But the gateway ip address for different routers are different and rpi will not get connected to a router if the static ip is not in the range. Therefore connecting to IITD WIFI at institute and using the same ip address in hostel will not work.

We create a hotspot in the device you want to connect to. Windows,Linux and Android are the OS's we worked on. All of them have in built application to create hotspot Android-settings->more->mobile hotspot, Windows 10->Connectify free third party application or install Ubuntu in Virtual box, Ubuntu->Go to network connection-> Edit connection-> click Add,choose Wifi and click create->Go to Ip4 setting and select to share with other computer. Now connect to this ssid we just created, your hotspot will be up and running. Hotspot gives the same ip address to device everytime it is connected based on its MAC address. Once you are connected to a hotspot, settings are saved in /etc/wpa_supplicant/wpa_supplicant.conf file. From desktop click on the network symbol and connect to each hotspot of your devices like android, windows. We can assign priority to each connection from the wpa_supplicant.conf file.

Now, you are in network and have the ip address for rpi. We can connect to terminal of rpi by connecting through ssh. Download Putty or any other ssh client. Type in the ip address, port 22 and connect. In case of Ubuntu OS, type sudo ssh your-rip-Address@pi command in terminal,we will be asked password which is raspberry and we are connected. Make sure to share internet over Rpi.

To install any program on rpi, internet access should be available for LXTerminal . To do this in IIT Delhi,Add the following line to

```
/etc/apt/apt.conf
```

```
Acquire::http \{ Proxy "http://repo.iitd.ac.in:9999"; \};
```

Type this in terminal to selectively apply proxy on every run

```
apt-get -o 'Acquire::http::Proxy="http://repo.iitd.ac.in:9999"' install
```

These settings are available on software repository page csc.iitd.ac.in. Now,

3.1.4 Virtual Network Computing(VNC)

VNC is a free third party application for remote access. Install vnc with this command

```
sudo apt-get install realvnc-vnc-server realvnc-vnc-viewer
```

Enable vnc through Menu > Preferences > Raspberry Pi Configuration > Interfaces. VNC is enabled. Everytime we want to start a server, it is best to open ssh create server using command vncserver :1 and connect to it from our device with ip–address and port opened. Note that rpi's HDMI port is :0 and so server cannot be created at :0. We can open multiple ports and open each virtual interface on different devices.

we can also set resolution of the virtual interface, vncserver :2 -geometry 1280x720 -depth 24 will create a virtual interface at port 2 with resolution 1280x720 and depth 24. In built browser available is chromium which does not have settings to change proxy. It uses system proxy settings. We could create a proxy file and save it in RPi configuration. Rather, using iceweasel browser is found to be more useful. It is similar to Mozilla firefox browser, proxy can be changed through preferences in browser menu. For installing iceweasel

```
sudo apt-get install iceweasel
```

3.2 WiFi access point on Raspberry Pi

Raspberry Pi 3 model has an on board WiFi which we can use it as a SoftAp for a ESP8266 sensor nodes because BCM43438 chip is supported by the open source *brcmfmac* driver. First we need to install required packages by following the step below

```
sudo apt-get install dnsmasq hostapd
```

- hostapd - With the help of this package we can use the built-in WiFi as an access point
- dnsmasq - Servers DHCP and DNS are combined and it is very easy to configure

First wlan0 interface must be configured with a static IP. By default dhcpcd handles the interface configuration. Since we are configuring wlan0 with a static IP we need dhcpcd to ignore it. In order to do that first we need to open the dhcpcd configuration file using

```
sudo nano /etc/dhcpcd.conf
```

and the following line is added to the bottom of the file

```
denyinterfaces wlan0
```

We have to configure the static IP of wlan0 by opening the interface configuration file and editing the section of wlan0.

```
allow-hotplug wlan0
iface wlan0 inet static
    address 172.24.1.1
    netmask 255.255.255.0
    network 172.24.1.0
    broadcast 172.24.1.255
```

After configuring the file dhcpcd needs to be restarted and then reload the configuration of wlan0.

For configuring hostapd we need to create a new configuration file containing the name, passphrase and it should use WPA2 for authentication and also use WPA-PSK as pre-shared key. Next, we need to configure dnsmasq to use interface wlan0 and assign a specific IP address range. Last thing we need to do is setting up IPV4 forwarding. For this we need to open *sysctl.conf* and set $net.ipv4.ip_forward = 1$ and by configuring NAT between the interfaces wlan0 and eth0 we can share RPi's internet connection to the connected devices.

3.3 Passive Infrared Sensor

In this section we will see how PIR sensors work. The PIR sensor has an IR sensor which is placed in a hermetically sealed metal can which has two slots in it, which has a material that is sensitive to IR. Both the slots detect same amount of IR rays when the sensor is idle.

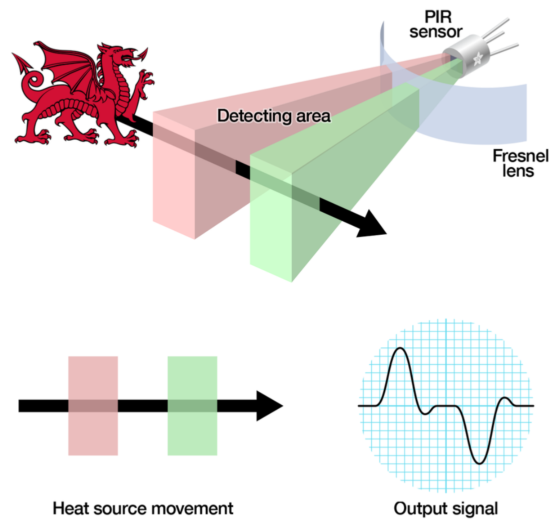


Figure 3-1: Working of PIR sensor

Source: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/how-pirs-work

When a warm body like animal or a human passes by and intercepts one half of the PIR sensor it causes a positive differential change between the two sensors. When the warm body is out of the detecting area, the second half is intercepted, thereby the sensor generates a negative differential change. Figure 3-1 shows the working of PIR sensor.

The PIR sensor has a Fresnel lens on top of it. This used because the Fresnel lens condenses light therefore have a detection area that is much larger, providing a larger range of IR to the sensor. As shown in the above Figure 3-1 instead of creating two large rectangle sensing areas we can rather scatter those into multiple small areas, for this purpose we use a lens which is split into multiple sections and each section of which is a Fresnel lens.

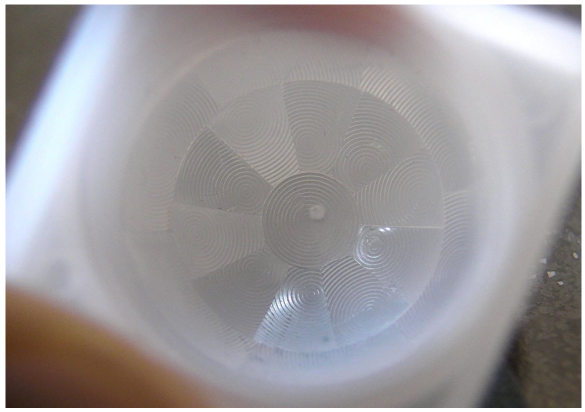


Figure 3-2: Macro shot showing the different Fresnel lenses in each facet

Source: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/how-pirs-work

These different lenses create a range of detection areas, interleaved with each other.As seen in the Figure 3-3 every other one points to a different half of the PIR sensing element[10].

3.3.1 PIR Sensor Experimental Results

Testing was done using three different PIR sensors. On average the field of view was 105° horizontally and 74° vertically. Range of the sensor is on average 6.25 meters in a dark corridor and 2 meters in an open field.

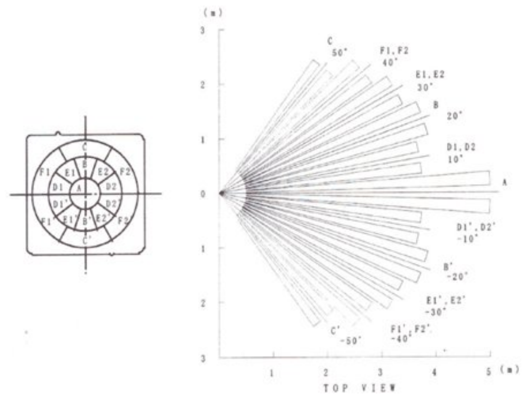


Figure 3-3: Splitting of the two sensing areas into multiple areas

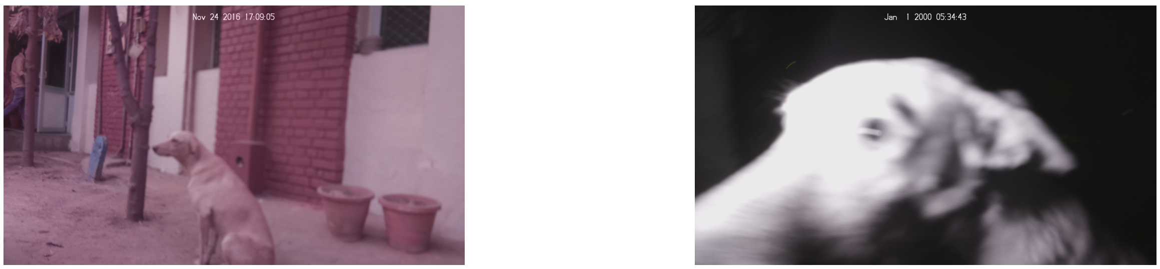
Source: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/how-pirs-work

3.4 Camera interface with Raspberry Pi (RPi)

As we mentioned earlier, Rpi has all the essential ports conveniently in-built. There is a port for camera. We download all the necessary modules from raspberry.org site through terminal. We need an external RTC(Real time clock) for getting the exact time. This is because there is no in-built clock in Rpi. There are two ways this issue can be resolved. First is to use an ntp server to synchronize the time on RPi all the time or use an external RTC. We are dealing mostly in forest so internet is not not option. Synchronization can only be done through internet. So, most realistic option is to use an RTC.

Now, Camera is coded using python to click only when PIR is triggered. This interfacing is done using GPIO pins(Input/Output) of Rpi. Naming the image is done based on the current date and time. Typical example for this is 20161115_012234.*jpg* meaning Date is November 15,2016 and time is 01:22:34 to second precision. Python code is executed on every boot using cron tab. Taking the photos is in a while loop. This will operate indefinitely until we manually switch it off.

We tested out the camera in presence of light and also using infrared flash at night. These are some images in Figure 3-4a and 3-4b for reference.



(a) Normal picture in presence of light. (b) Picture in the dark with IR flash.

Figure 3-4: Images taken by NoIR camera in different settings.

3.5 Our Camera Trap

After assembling and setting up of all the components we obtain our hardware part of out project, the Camera Trap see figure 3-5

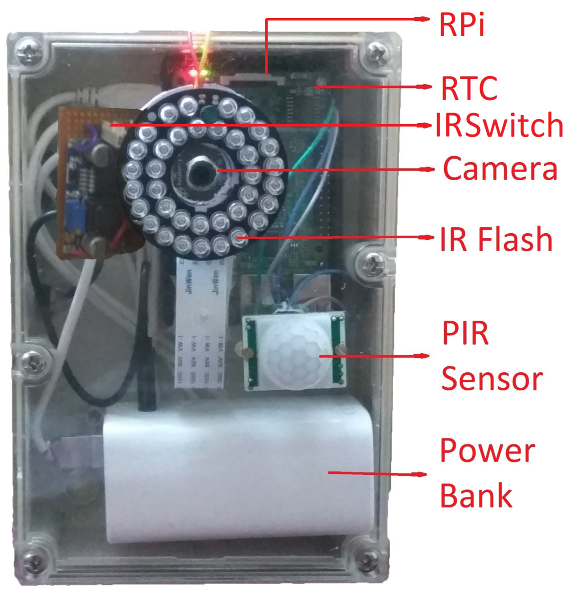


Figure 3-5: Our Camera Trap

Figure 3-6: Our Camera Trap

Figure 3-7: Bushnell Camera

Chapter 4

Design of Application Interface for Data Transfer from Camera Trap to Android

4.1 Introduction to File Transfer Protocol

For data transfer from the Raspberry Pi, File Transfer Protocol (FTP) was used. FTP is a standard network protocol. It is mainly used to transfer files between devices on the same network using the client–server model, where one acts as a server which provides resources or service and another as a client which requests for services. Here, the Raspberry Pi acts as an FTP server and the Desktop or a Smart phone acts as FTP client. After a successful login files can accessed and can be transferred from Raspberry Pi to a Desktop or a Smart phone. We used FTP because it was easier to implement than HyperText Transfer Protocol (HTTP).

4.2 File Transfer Protocol on Raspberry Pi

The FTP has two modes active and passive, these modes determine how the data connection is established. The client randomly creates a TCP control connection from usually an unprivileged port N to the FTP server command port 21 for passive mode and port 20 for active mode.

Android and Desktop has an in built Object Push Profile (OPP). So, in order for OPP client devices to connect to Raspberry Pi we need to make Raspberry Pi an OPP server. The network connection between Raspberry Pi and Desktop or Smart phone is made through WiFi. Raspberry Pi is made into a WiFi hotspot and then Desktop or Smart phone is connected to it. We have used vsftpd package for Raspberry Pi to create an FTP server. By default any device has ports 20 and 21 as FTP ports. If we have IP address of a device, we can sign in using a user login of a particular device.

4.3 Android Application

4.3.1 Application Interface

Since we only wanted to download and display the images taken by the Camera Trap which is stored on Raspberry Pi, the interface was simple and similar to a gallery application. When the android application is opened the user has to enter the login details (see fig:4-1) for the FTP server on the Raspberry Pi. After a successful login the user is brought to a home screen (see fig:4-2) with different options to select from.

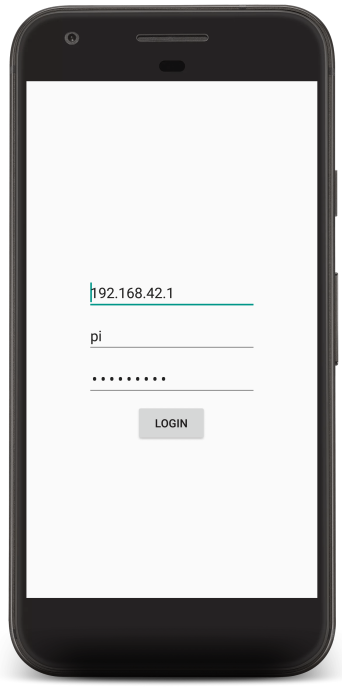


Figure 4-1: Login screen

Figure 4-2: Home screen

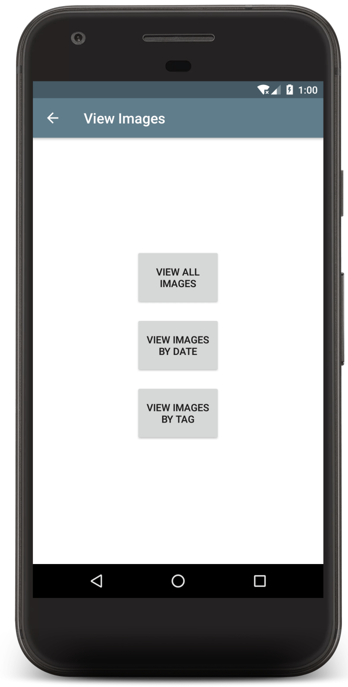


Figure 4-3: Sub menu

- View Images - By clicking this button the user is brought to another screen (see fig:4-3) where there are options to view particular set of images like images tagged with specific names or images taken between specific days.

- Download Images - By clicking this button the user is brought to another screen where there are options to download particular set of images to the local storage of the device, like images tagged with specific names or images taken between specific days or all the images on the Raspberry Pi.

- Delete Images - By clicking this button the user is brought to another screen where there are options to delete particular set of images from the Raspberry Pi, like images tagged with specific names or images taken between specific days or all the images on the Raspberry Pi.

- Local Gallery - By clicking this button images that have been downloaded will be displayed in a grid list like a normal gallery application.

- Clear Cache - By clicking this button the temporary images would be deleted from the memory.

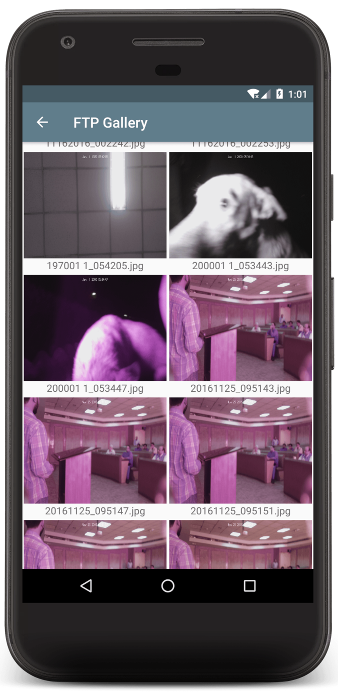


Figure 4-4: Gallery screen

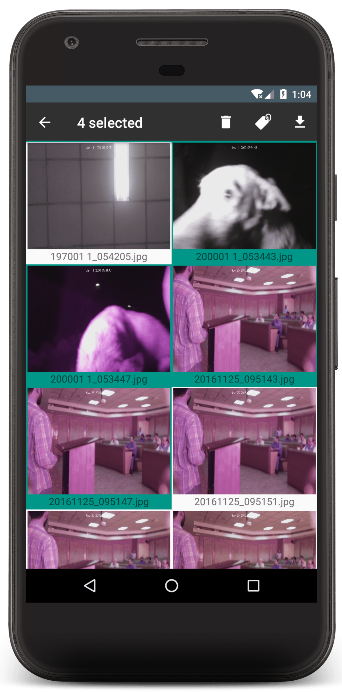


Figure 4-5: Mutli-select

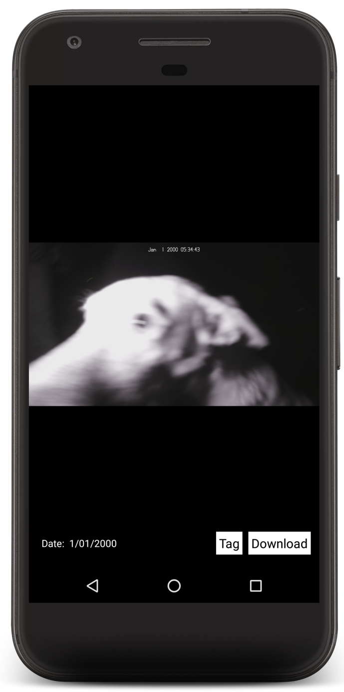


Figure 4-6: Single image

When the user clicks on any of the images while viewing they are brought to a screen (see fig:4-6) where the user can interact with that image. In this screen the user can zoom in and out of the image or tag the image with specific names or download it to the local storage of the device. By long pressing any of the images the application enters into multi–select mode (see fig:4-5), where the user can select multiple images and can either download or delete or tag the all the selected images at once.

4.3.2 Functions

The android application was designed using standard libraries on Android Studio. The library that was used for FTP is Apache Commons Net developed by ORO, Inc. By using Apache Commons Net library we can create an FTPClient object. This FTPClient object contains all the basic functions for logging in and out, downloading or deleting files, etc. With these functions we can implement the functions necessary for retrieving required images from an FTP server i.e from Raspberry Pi. All the classes that were derived from SocketClient must first connect to the server using connect function, also we need to check the FTP response code to check if the connection was successful or not and finally disconnect from the server using disconnect function after we have completely finished interacting with the server.

The code down below is used for connecting to the server. The input parameters required are host address,host port,user id and password.

```
// This function is used for connecting to FTP server:
public boolean ftpConnect(String host,String username,
                          String password,int port) {
    try {
        mFTPClient = new FTPClient();
        mFTPClient.connect(host, port);
```

```
//if the boolean in the if condition is true
//the connection is established
        if (FTPReply.isPositiveCompletion(mFTPClient.getReplyC
            boolean status = mFTPClient.
            login(username, password);

// Set File Transfer Mode BINARY_FILE_TYPE is used for
// transferring texts, images, and compressed files.
            mFTPClient.setFileType(FTP.BINARY_FILE_TYPE);
            mFTPClient.enterLocalPassiveMode();

//boolean status would return true if the login was successful
            return status;
        }
    } catch (Exception e) {
        Log.d(TAG, "Error: unable to connect to the host " + h
    }
    return false;
}
```

So we need a host address,host port,user id and password of the FTP server. Once we successfully login to the server we can get the list of files and directories present in the Raspberry Pi.

In the Login screen the user has to enter the address of the ftp server and the port. The user id and the password is set accordingly while setting up the ftp server on Raspberry Pi. When the login button is pressed the ftpConnect function in the FTPClient object is executed with the input parameters taken from the text fields.

All the network functions are run in different threads because these functions might obstruct the main code from executing while waiting for the response back from the server. Threads are mainly used to perform asynchronous or background processing and we can also take advantage of multiprocessor power present on the android devices.

There is a download button for each image when viewing a single image (see fig:4-6), when the button is pressed it executes the ftpDownload function in the FTPClient object which downloads the image to the internal storage of the device.

4.3.3 Cache Implementation

Every time we open the gallery screen, it loads the images stored on the FTP server i.e. Raspberry Pi just for viewing. Since we would be storing hundreds or may be thousands of images taken by the Camera Trap, to load all the images at once will take a lot of time and usually its not the best way to do it because it puts a lot of load on the cpu of the device.

Caching is storing data which was requested so that future requests for the same data can be served faster. We implemented cache hit and cache miss system for the above problem. So whenever we open the gallery the images that are visible on the screen are loaded first in separate threads since network functions have to wait for the response from the server and it takes different times for different images and then it is stored on local storage of the device. Whenever a new request is made it checks for the image in the cache and when cache hit occurs that image is loaded from the cache on the local storage, if cache miss occurs a download request is sent to the FTP server on a separate thread. In this way the images are loaded faster and puts less load on the cpu of the device.

Chapter 5

Results and Conclusions

5.1 Summary

Our objective was to create a economic camera trap suitable even for harsh condition of our country, India. We have designed a camera which triggers on motion detection and takes pictures automatically. We did a comparative study on the specifications our present market provides and included better means of communication like Bluetooth and WiFi. From the market analysis we were able to decide on which features to focus on. Then we decide on the components required for those specific features like the camera, pir, gps, IR flash etc. Based on some primary goals and after some analysis and calculation we determined the resolution of the camera, type of container in which the device is going to be placed, battery capacity, communication with the device, etc. The tools that we used Raspberry Pi 3 Model B, 5MP NoIR Camera, 10400mAh power bank, 36 IR led's angular array, 16GB memory card, Buck boost converter, IRFZ44N Mosfets, vsftpd package for FTP server, Android

Studio for android application, Apache Commons Net for FTP client. We have used a plastic box for the prototype, but will use high grade plastic plastic like polypropylene for actual product to protect it from harsh environment and animals. After setting up the Raspberry Pi, making it as a hotspot and an FTP server any user with authentication can login and view the images taken by the camera trap. These images are taken only when the pir sensor is triggered. So when the pir sensor is triggered it sends a signal to Raspberry Pi which then triggers the IR flash and camera. We developed an android application which acts as an FTP client which can connect to the FTP server i.e Raspberry Pi and download all the images which are stored on it which were taken by the camera trap.

5.2 Results

The results that we hope to obtain at the end were the images of the animals in wild. The process to get these images were to camouflage the device and tie it to the trunk of a tree using strong velcro straps. Then the camera trap would take pictures of animals which trigger the pir sensors on it. In order to get those images we need to go close enough to the camera trap to connect to its hotspot from a Smartphone and then open the android application and login to the FTP server to download the required images and delete the images on the FTP server to free the storage space on the camera trap.

5.2.1 Significance and Interpretation of the Results

After implementing a network of camera traps in the wild, images of different animals that we obtain from these camera traps can be used in number of ways. For example, from the data that we obtain from the images we can use it to track animals, detect a number of rare species, determine the migration of animals, determine prey to predator ratio, estimating population size by using a method known as distance sampling, detection of possible forest fire, etc.

5.3 Future Work

5.3.1 What I could have done?

- We had problems with power optimization using PIR sensors.
- Include a battery compartment for AA batteries and detachable power bank.
- Camera could be used with a lens for better photography.
- Common cross platform tool for data transfer and interaction with the device.

5.3.2 What more can the next person do ?

- **Tracking** - In Essential tools section we calculated the resolution of camera based on identification of animals specifically tiger as an example. Animals can be identified based on their age, height, bodily scars etc. If enough cameras are placed at different points in forest, we could create a machine learning application to track the movement of specific animal to their habitat.

- **Predator to prey rati**o- Ecological balance is a state of dynamic equilibrium of organisms in which genetic, species and ecosystem diversity do not change significantly. [3] We can analyze the data of photographs from cameras in an area and determine the predator to prey ratio. Lokta-Volterra Equation gives us the base value of the ratio between any two species.[4] Prey population increases at the rate of

  $$dx = Axdt - Bxydt$$

  and predator population increases at the rate

  $$dy = Dxydt - Cydt$$

  . These equations can then be used to monitor the ratio and determine the necessity of human intervention. We can also introduce one species from a different locality to the surveyed location if there is a chance for their survival

- **Migration of animals**-Reasons for animal migration can be availability of food, for mating reasons, local climate change and also as a part of habitat change. Scientists track the migration by identification tags, radio collar tags. But only some of these tags are recovered and most are just lost. Camera traps can serve as a better replacement for tracking these migratory animals without in anyway disturbing their life style

- **Estimating population size by distance sampling**- This is a most common method for estimating population density of a species in an area. This is based on an underlying principle that as the distance between observer and animal increases the probability of detecting an animal decreases. Animal density is the number of animals in a unit area of observation. Probability of occurrence of an animal in an area gives the detection function of a particular animal at a point. Using distance sampling we can estimate the detection function along a line and thus by calculating the density of population and detection function we can estimate population of an entire region [2]

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