Smart Trap

Team 63

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Objective and Background

Goals:

- Our product solves the problem of animal traps accidentally capturing animals other than the ones that are being targeted (i.e. a dog instead of a raccoon).

Functions:

- This product uses a camera to monitor the cage as well as machine learning to accurately detect the creature entering the cage.
- This product prevents the trap from trapping any undesired animal by using a motor attached to a pin on the pressure plate.
- This product uses a common 18V tool battery to power the system.
- This product uses sensors to conserve power of the system during the day and when no creatures are nearby.

Benefits:

- The product will reduce the risk of unintentionally trapping undesired creatures, thus reducing the risk of pets and children.
- A fully charged battery can last at least 12 hours.
- It is energy-efficient since the product will be activated only when animals are around.
- The device is a modular add-on, so those who own pressure plate traps do not have to buy an entirely new trap.

Features:

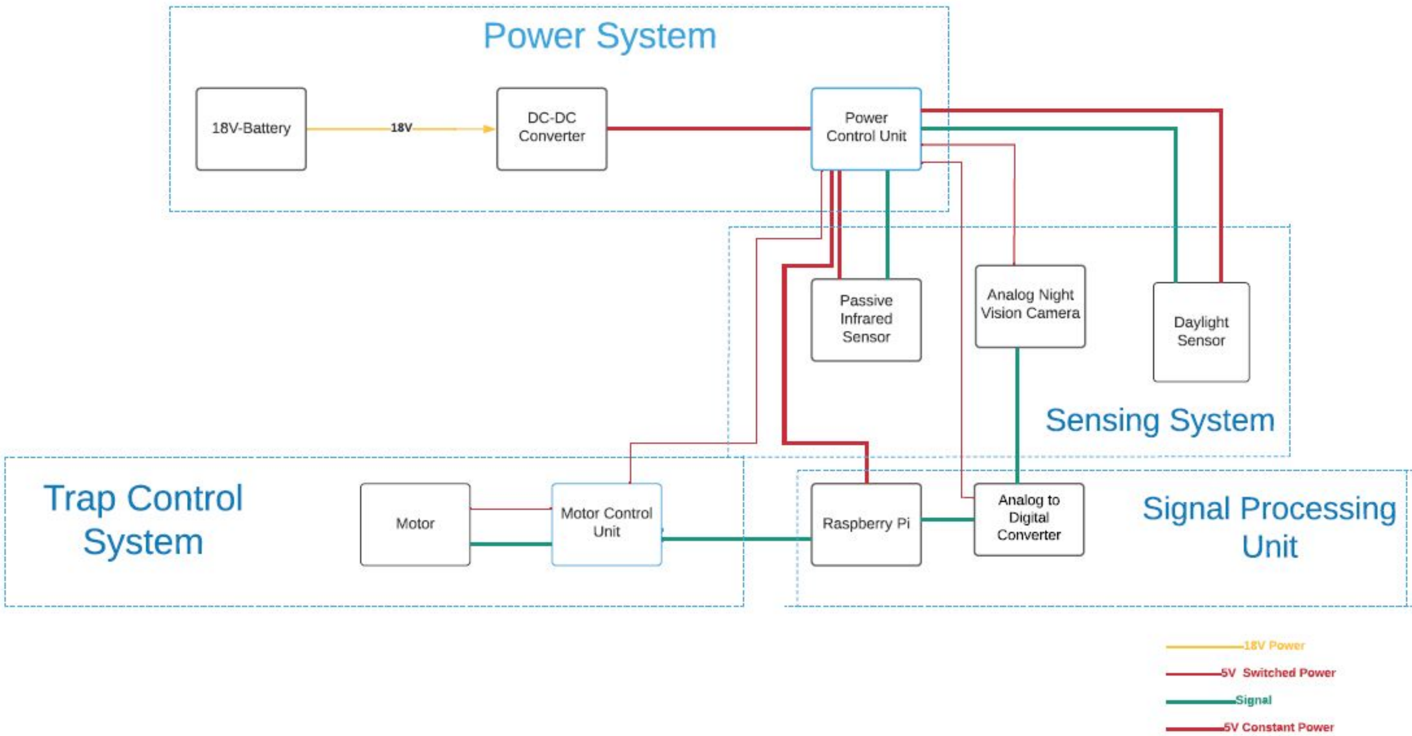
- The product can be marketed particularly to pet owners. The product would be most appealing to pet owners who allow their pets to roam free outdoors, such as on a farm. In such settings, a trap is more likely used to protect the farm. Our product allows these pet owners to never worry about their pets becoming trapped.
- The product will not be costly since all components are inexpensive.
- There is no similar solution in the market at this time.

High Level Requirements

- Our trap should have an accuracy of at least 95%. That is, the trap should only mistakenly trigger at most 5% of the time. The trap should fail safely, meaning that it is more desirable to let the target animal leave untrapped than to capture the wrong animal.
- Our trap should run on 18 Volts and have a minimum of twelve hours of battery life.
- The trap should make a decision within five seconds of the animal entering the cage.

Above:
An example of the type of trap that our device should connect to. This pressure plate trap does not harm the animal, as it simply closes the door to the cage.

Block Diagram



Subsystem Descriptions and Requirements

Signal Processing:

The signal processing unit consists of the ARM Cortex-A53 processor on the Raspberry Pi, which processes the image and implements an object detection machine learning algorithm for detecting a creature. The signal processing unit also consists of a digital signal processor to convert the analog RCA video jack to a digital USB.

Analog to Digital Converter:

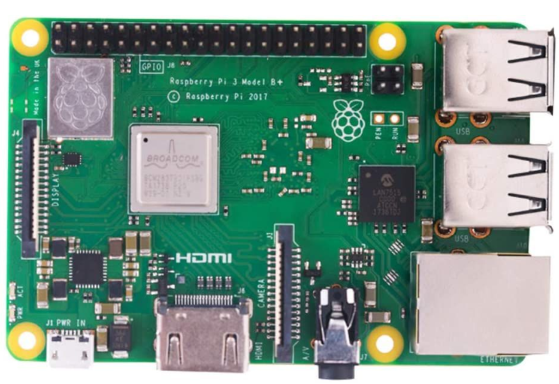
The Analog to Digital Converter takes in the analog signal via the RCA video cable and digitizes it through the USB 2.0 cable. The converter has a video resolution of 720x480 pixels at 30 fps.

Raspberry Pi:

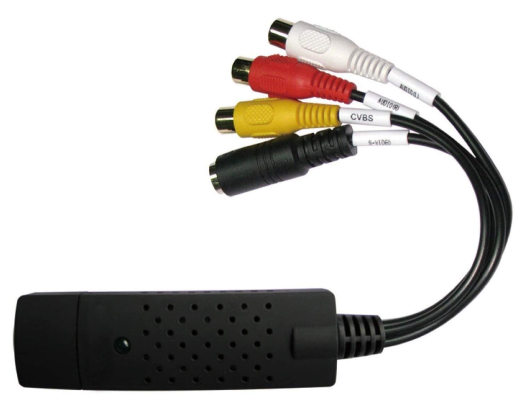
The Raspberry Pi has a ARM Cortex-A53 quad core processor clocked at 1.4GHz with 4 × USB 2.0 ports and Extended 40-pin GPIO header. The Raspberry Pi handles the image processing from the camera by taking in the data through the USB 2.0 port, implementing the object detection algorithm on the image, and applying a 3.3V signal output to the motor control unit via the GPIO pins. This output merely communicates with the mtor control circuitry; it does not supply power.

Requirements:

1) The sample rate of the analog video input used by the Raspberry Pi should be at least one frame every two seconds.
2) The Raspberry Pi should boot up and run the object detection program immediately.
3) Subsequent boots and shutdowns should not compromise the functionality of the program.
4) The program must handle the case where there is no input from the camera.
5) The Raspberry Pi should consume at most an average of 4.5W. This number should be minimized as much as possible, perhaps by implementing an interrupt signal that tells the Raspberry Pi when to idle and cease computations.



Above:
The Raspberry Pi 3 Model B+



Above:
RCA to USB 2.0 converter

Trap Control:

Trap Control System consists of a motor and motor control unit. Motor control unit receives a bool signal from the Raspberry Pi to control whether to turn on or off the motor. And the Power Control Unit will assign less than 5 volt power to it once Raspberry Pi sends the bool signal. Motor control unit sends signals to the motor. Motor will be a 90 degree servo motor with the default state preventing the pressure plate from activating.

Requirements:

1) The motor/solenoid arrangement must be subtle enough to not scare an animal away. This includes any noise from gears. This can be quantitatively accounted for when testing the trap, as this will affect the overall efficacy.
2) The motor control unit should not consume any power at idle while still effectively blocking the pressure plate.
3) The motor control unit should not consume any power in steady state while an animal is in the trap. The only use of power should be momentarily opening and closing the pressure-plate disable mechanism.

Power Supply and Control Requirements:

The power system consists of an 18V battery, a DC-DC converter, and a power control unit. The 18 volt input must be converted to several different voltage levels, including 3.3 and 5 volts in a self-built DC-DC converter. The power control unit is able to switch power to all systems based on need parameters which include time of day and the proximity of an animal. The 18V battery is charged by whatever charger is supplied by the battery manufacturer. The charger is not a part of our device. This is desirable because our device does not rely on incompatible, proprietary technology. It is instead able to be used with commonly available consumer battery technology.

DC-DC converter:

The 18 volt input must be converted to several different DC voltages, including 3.3, 5, and 9-12 volts. We will use a buck converter to reduce the voltage. The converter also serves as a voltage controller, outputting fixed voltages.

Power Control Unit:

The power control unit takes the reduced voltage signal from the DC-DC converter and distributes it to the different components in the project. The power control unit distributes power to the PIR sensor, Analog night vision camera, daylight sensor, motor control unit, and the Raspberry Pi. The power control unit will also incorporate TTL circuits to offload computation power from the raspberry pi.

Requirements:

1) The input to the entire system must be a commonly available 18V-20V tool battery. Brands of such batteries include Ryobi, Dewalt, and Milwaukee.
2) The power supply must be able to output the DC voltages needed by the Raspberry Pi (4.5W , the analog camera, and the sensors used. The logic will be run from the lowest of these voltages.
3) The power control system must switch power to the camera and the motor controller. This switching is controlled by the passive infrared sensor.

Above:
Example of a common 18V tool battery

Sensing Requirements:

Our sensing system consists of three parts: a daylight sensor, a PIR sensor, and a night vision camera. The daylight sensor detects the ambient light. This is used to turn the device off during the day if desired. This function will conserve battery life when trying to catch nocturnal animals. The PIR sensor allows the camera and Raspberry Pi to idle when no animal is present near the trap. Once movement is detected, signals will be sent back to the power control unit to activate the night vision camera and to take the Raspberry Pi out of idle. Note that the state of the door does not have to be sensed. The door can only close if the pressure plate is triggered. This can only happen if the target animal is detected which unblocks the pressure plate.

Security Camera:

A 300 x 380 analog pixel camera which outputs video to the RCA cable, the RCA cable is then hooked up to the RCA to USB converter which allows the image to be processed by the Raspberry Pi. The camera is weatherproof and contains low light infrared LEDs that allow the camera to work during the night.

Photoresistor:

For our sensor, we will use CdS photoresistor. As the squiggly face is exposed to light, the resistance goes down. When the ambient light is brightest, the resistance is about 1kΩ. When there is little ambient light, the resistance is about 10kΩ. It will be connected to the power control unit.

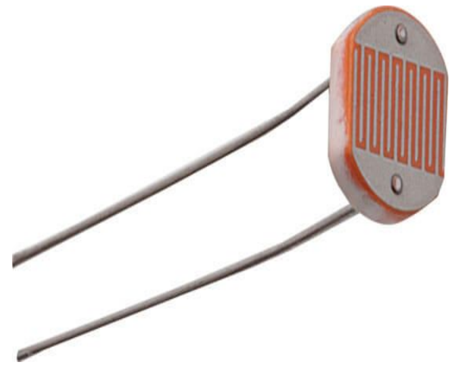
Passive Infrared Sensor:

The PIR sensor is used to detect if a creature approaches the cage, and is connected to the power control unit to turn the system into a low power state whenever there are no creatures in the vicinity. The sensor works by detecting the infrared light emitted by the heat of animals or people passing through the detection area, and outputting an associated voltage (positive when entering the detection area, negative when leaving the detection area). The PIR sensor takes in a 5V input from the power control unit and outputs a voltage back to the power control unit.

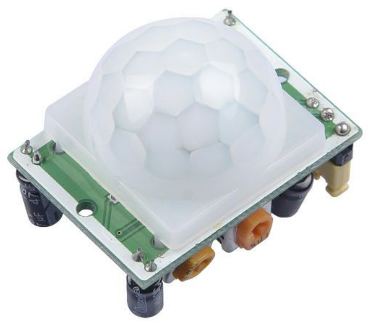
Requirements:

1) The passive infrared sensor should consume no more than 2mW. Preferably, it should consume less than 0.5mW. Operating voltage for the PIR sensor should be between 3.5V-5V.
2) A simple photocell will be used for daylight detection. The daylight sensing circuit should consume as little power as possible such that the main battery life goal can be achieved.
3) The analog night vision camera must only be turned on when the PIR sensor detects movement.
4) The analog night vision camera must have a minimum resolution of 240 pixels in any direction. The camera will likely have a square image because we intend to use one meant for security applications.

Above:
Example of a security type, low light, analog camera



Above:
Example of a photoresistor, to be used in the daylight sensing circuit



Above:
Example of a passive infrared sensor

Risk Analysis

The component which will be the most difficult to implement is the object detection program that will run on the Raspberry Pi. This part of the project will undoubtedly be the hardest to implement for several reasons. The core functionality of this product depends on its “smart” capabilities. Our object detection must distinguish between different animals in a low light setting. This program is inherently linked to two of our high level requirements; the device must perform quickly and the device must perform accurately. Adding to the complexity, our input will have to be sampled from an analog source. We intend to begin developing this subsystem by obtaining a camera within our specifications and then using a laptop computer to create and test our object identification program. Once the program works in this test setup, we will need to consider the performance on the Raspberry Pi, which is computationally limited. Creating a proper port of our program is essential to having this be a modular device. Next, we will have to consider the power consumption. At idle, the Raspberry Pi power consumption is not an issue. Our back of the envelope calculations indicate that we will have plenty of runtime under such conditions. However, the power draw under computational load will be far greater than idle. For this reason, we plan to have an interrupt signal that tells the program when to run and when to idle. Furthermore, we plan to have a single output from the Raspberry Pi such that all other tasks are offloaded from it. This single output will be boolean: is the proper animal detected or not.

Ethics and Safety

- Our product holds paramount the safety, health, and welfare of the public. The maximum Voltage is designed to be 18V. Therefore, it will not be harmful to any animals or human beings.
- Our testing process will be conducted with a pet cat, and will follow the USDA Animal Welfare Act and the NIH Public Health Service Policy as stated by Illinois Institutional Animal Care and Use Committee.
- No hazardous or volatile materials are used in our project. All components we will use are consumer grade and can be purchased legally online.
- All group members have completed lab safety training according to the safety guidelines of UIUC.

Citations and References

[1] Raspberry Pi Foundation, "Raspberry Pi 3 Model B+ Product Brief", Available: https://static.raspberrypi.org/files/product-briefs/Raspberry-Pi-Model-Bplus-Product-Brief.pdf. [Accessed Feb. 17, 2021].

[2] Bunker Hill Security, "Weatherproof Color Security Camera Manual", Available: https://manuals.harborfreight.com/manuals/95000-95999/95914.pdf. [Accessed Feb. 17, 2021].

[3] Adafruit, "PIR Motion Sensor Data Sheet", Available: https://cdn-learn.adafruit.com/downloads/pdf/pir-passive-infrared-proximity-motion-sensor.pdf. [Accessed Feb. 17, 2021].

[4] Adafruit, "Photocells Data Sheet", Available: https://au.mouser.com/datasheet/2/737/photocells-932884.pdf. [Accessed Feb. 17, 2021].

[5] "Buck Converter – Circuit, Design, Operation and Examples", *electricaltechnology.org*, Available: https://www.electricaltechnology.org/2020/09/buck-converter.html. [Accessed Feb. 17, 2021].

[6] J. Brownlee, "A Gentle Introduction to Object Recognition With Deep Learning", *machinelearningmastery.com*, May 22, 2019. [online]. Available: https://machinelearningmastery.com/object-recognition-with-deep-learning/. [Accessed Feb. 17, 2021].

[7] "Servo Motor SG-90", *components101.com*, Available: https://components101.com/motors/servo-motor-basics-pinout-datasheet. [Accessed Feb. 17. 2021].