Automated Video Capture Bird Feeder with Data Collection

ECE 445 Senior Design Project Proposal

Team #10

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1. Introduction

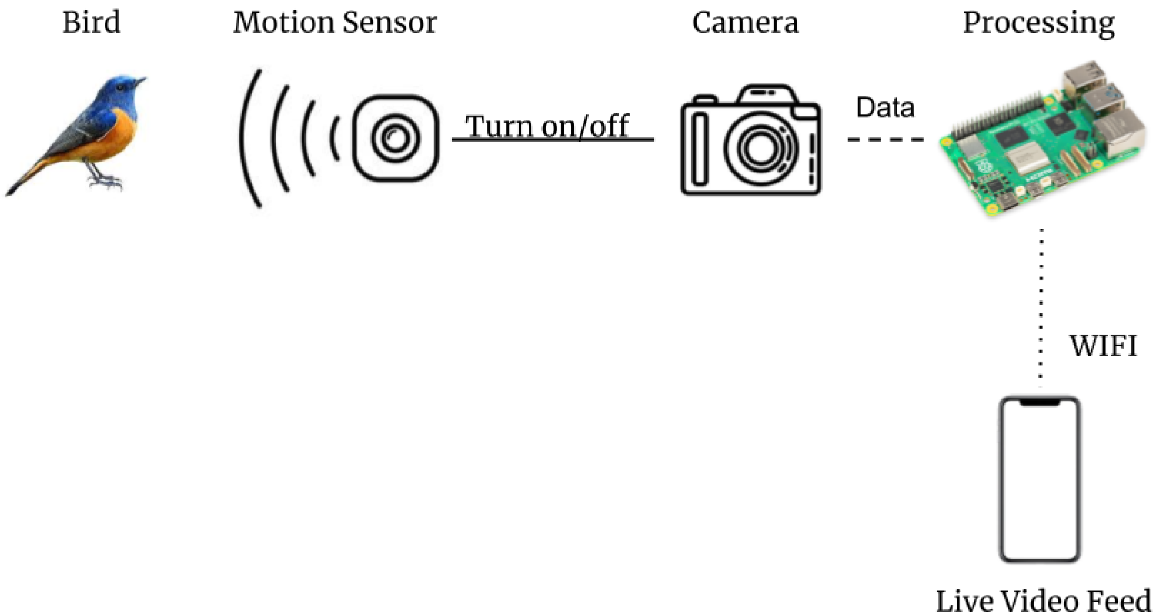
1.1. Problem

Many nature enthusiasts enjoy watching birds outside their windows with homemade or store-bought feeders. This practice has been going on for many years, but until recently it has been impossible to see the birds feeding without being present. With modern-day technology, it has become possible to mount cameras onto or adjacent to bird feeders to see birds feeding, but in the new era of information technology, there should be more to bird feeders than simple footage. We seek to add onto an automated video capture system by including data capture to analyze when peak feeding hours occur. This problem occurs for common bird watchers and ornithologists alike. Whether it is knowing when to sit in front of your bird feeder or wanting to collect feeding data in specific areas, this is a problem that necessitates a solution.

1.2. Solution

The solution we propose involves a bird feeder that has a camera to turn on when motion is detected. The idea is to have an ultrasonic transducer that would trigger a camera to record for a given set of times if motion is detected. In addition, specific data points that would benefit nature enthusiasts would be acquired and stored. These would include time intervals when birds arrive to identify peak bird times. We also want the end user to be able to view live footage of the bird feeder via a website URL. Our solution would implement all of this by using a power pack located on the bird feeder that supplies power to the camera, motion detector and microcontroller, with the raspberry pi having a separate power supply that all work in tandem to create our final product.

1.3. Visual Aid



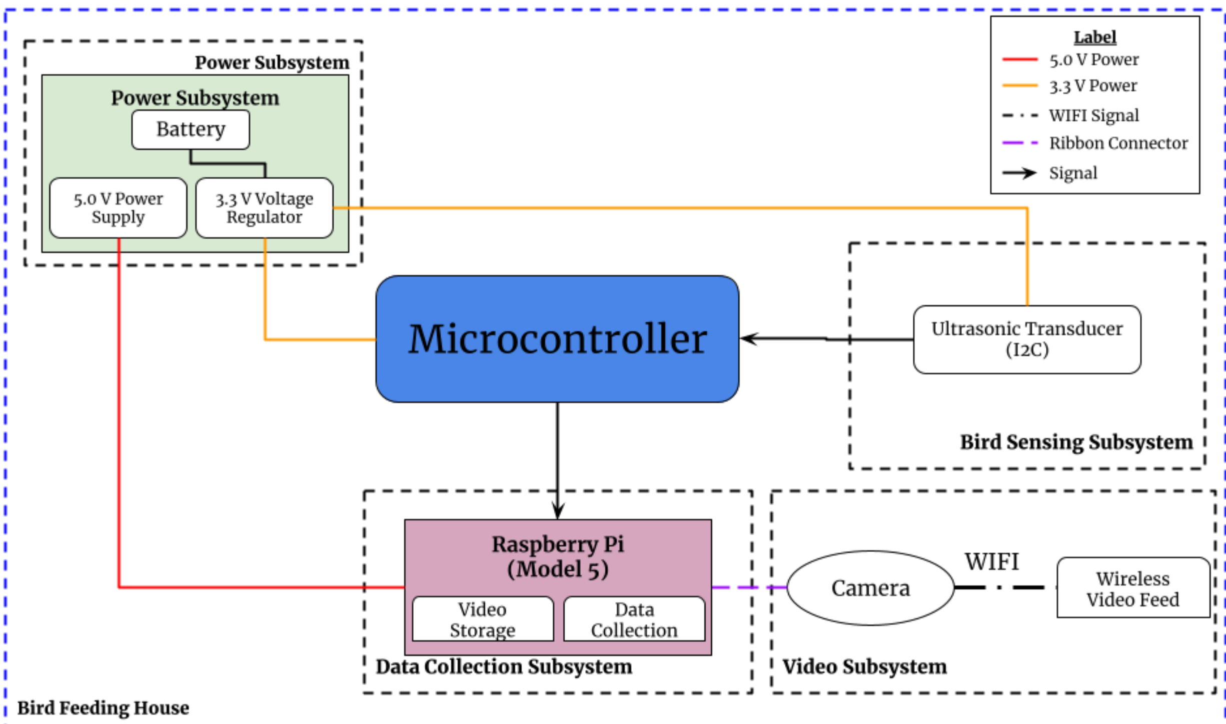
1.4. High-Level Requirements

- Activate the camera within 10 seconds of a bird landing, correctly identifying bird presence with 90% accuracy.
- Deliver a live video feed to the user device with a resolution of 720p or higher, while displaying the feed with a delay of no more than 15 seconds.
- Turn off the camera 30 seconds after the bird departs. The camera should stay on if motion is detected within the birdhouse during the timeout period, while minimizing false positives triggered by wind, leaves, or other non-bird movements.

2. Design

2.1. Block Diagram

- Microcontroller: Controls camera and sensor, triggers recording based on ultrasonic detection.
- Ultrasonic Transducer: Detects bird movement and sends signals to the microcontroller.
- Raspberry Pi: Stores video recordings, power the camera. and manages data collection.
- Camera Module: Connected with a ribbon connector to the Raspberry pi and captures video footage of the bird.



2.2. Subsystem Overview

2.2.1. Subsystem 1 - Video Capture

This subsystem focuses on capturing video footage triggered by the ultrasonic transducer. Components include an ultrasonic transducer to detect motion and alert the camera to start recording, a microcontroller for processing video data and triggering the camera system as well as transmitting bird tracking data, and a camera that will take videos of the birds feeding.

2.2.2. Subsystem 2 - Data Collection

Data Collection will be important to the end user and so require a separate system to ingest the data and store it properly for later usage. This will require connections to other subsystems to check for example if the camera is turned on and will require a storage component in addition to a processing unit. The storage component will be a ssd used by the processing unit which will be a raspberry pi 5.

2.2.3. Subsystem 3 - Power System

A power system is required to power the other subsystems and during testing, this will be done through a DC power supply with potentially additional voltage regulations. It is important to also have a separate power supplied to the raspberry pi as the power draw is high and it is vital to have quality voltage and current control to the raspberry pi. The raspberry pi 5 was bought personally and will be used for future projects and so we will be avoiding soldering anything onto the raspberry pi 5.

2.2.4. Subsystem 4 - Bird Feeder

The bird feeder subsystem is the physical enclosure that stores the bird seed as well as houses all the electronic components. This means that fire hazard concerns need to be taken into account as well as protective measures for the camera due to the outdoor location of the bird feeder. The camera must also be protected from the elements while maintaining unimpeded motion capture.

2.2.5. Subsystem 5 - Real-time video feed

This subsystem will display the real-time video feed from the camera through components such as a web application. It will also require a processing unit like in the video capture subsystem which will not only store the video feed but broadcast it to be viewed. The broadcast will be done via WIFI and the raspberry pi will serve as a host to allow a remote device to connect and view the stream and data.

2.3. Subsystem requirements

2.3.1. Subsystem 1 - Video Capture

The subsystem, composed of a Raspberry Pi, camera, camera ribbon, and SSD, is responsible for initiating video recording upon receiving a signal from the microcontroller and storing the captured data on the SSD. We have focused on three primary aspects: timeliness of recording start, video data processing rate, and video quality. Below is the specific requirements and verification methods for each key aspect:

Requirement	Verification
Timeliness of Recording Start: **1.** Raspberry Pi should initiate recording within 10 seconds upon signal from the microcontroller.	**1.1.** Measure the time delay between signal reception and the start of video recording using a timer. **1.2.** Repeat the measurement multiple times and calculate the average and standard deviation of the delay. **1.3.** Ensure the average delay is less than 10 seconds.
Video Data Processing Rate: **2.** The Raspberry Pi processes video data at an average rate of 0.4 MB/s in SD resolution.	**2.1.** Capture a short video clip (10 seconds) and measure the file size. **2.2.** Calculate the processing rate (data size / recording time) in MB/s. **2.3.** Repeat the measurement several times with different lighting conditions and object movements. **2.4.** Ensure the average processing rate is close to 0.4 MB/s.
Video Quality: **3.** The recorded video clips should be at least 720p resolution	**3.1.** Capture a short video clip (10 seconds). **3.2.** Manually review recorded video clips for artifacts, blurriness, or excessive noise.

3.2.1. Subsystem 2 - Data Collection

The data collection subsystem focuses on collecting and storing data. This involves creating CSV files on the Raspberry Pi at regular intervals, ensuring they arrive on time, contain the correct information in the proper format, and are securely saved on the SSD. Below is the specific requirements and verification methods for each key aspect:

Requirement	**Verification**
Time of CSV Generation: **1.** The Raspberry Pi generates a new CSV file within 10 seconds of the designated time interval.	**1.1.** Record the timestamp of CSV creation. **1.2.** Calculate the time difference between the expected and actual creation times. **1.3.** Repeat the measurement multiple times and analyze the distribution of time differences.
CSV File Content: **2.** The CSV file contains all necessary data columns in the correct format.	**2.1.** Manually view the CSV file to view the data and see if the data is there.
CSV File Storage: **3.** The CSV file on the SSD has a unique and identifiable filename.	**3.1.** Manually check the filename of the generated CSV file to make sure it has the timestamp.

3.1.1. Subsystem 3 - Power system

The power system ensures consistent voltage delivery for the raspberry pi and the microcontroller, guaranteeing smooth operation for both components. The raspberry pi requires 5.0 volts and the microcontroller requires 3.3 volts. By measuring and monitoring the voltage during various operating conditions, we can verify its stability and avoid potential power-related issues. In the initial development stages, this subsystem takes power from a wall outlet and for the final product it will be using a battery. Below is the specific requirements and verification methods for each key aspect:

Requirement	**Verification**
Raspberry Pi: **1.** The power system should supply dc voltage to the Raspberry Pi between 4.75 - 5.25 volts [5]	**1.1.** Connect a voltmeter to the 5.0V voltage regulator power output **1.2.** Run the system through various operating scenarios (including idle, high load) **1.3.** Ensure the voltage stays within 4.75 - 5.25 volts
Microcontroller: **2.** The power system should supply dc voltage to the microcontroller be 3.3 volts ± 0.2 volts	**2.1.** Connect a voltmeter to the 3.3V voltage regulator power output **2.2.** Run the system through various operating scenarios (including idle, high load) **2.3.** Ensure the voltage stays within 3.1 - 3.5 volts

2.3.1. Subsystem 4 - Bird Feeder

The bird feeder houses the raspberry pi and the microcontroller and power supply keeping it safe from the elements. The ultrasonic transducer and camera will also be mounted on it to keep everything stable.

Requirement	**Verification**
Transducer Performance in Simulated Weather **1.** Transducer does not detect motion from severe weather	**1.1.** Connect the ultrasonic transducer and place it near a fan **1.2.** Start the fan at low intensity and gradually increase it to represent severe weather conditions. **1.3.** Continuously monitor the transducer output. If any motion is detected during this process, consider it a failure
Transducer Protection from weather **2.** Transducer does not get damaged in severe weather	**2.1.** Visually inspect the mounted location of the transducer. Ensure it is fully sheltered from direct rain, snow, or hail. **2.2.** If necessary, adjust the mounting position or add a protective cover to shield the transducer from water exposure. **2.3.** Document the chosen protection method and its effectiveness in preventing water damage.
Environmental Protection for all electronics **3.** The enclosure housing the electronics must be weatherproof	**3.1.** Visually inspect the enclosure for proper sealing around seams, ports, and cable entries. **3.2.** Conduct a water spray test to verify the enclosure's resistance to rain and splashing water.

3.2.1. Subsystem 5 - Real-time Video Feed

This system is using the raspberry pi as a broadcasting server. Either via a web server or a direct connection a user should be able to see video streaming.

Requirement	Verification
Stream Delay: **1.** Delay between the stream and live should be within 15 seconds	**1.1.** Set up a simple test environment with the camera capturing both the live feed and recording for streaming. **1.2.** Simultaneously introduce a visual cue (e.g., hand wave) in front of the camera. **1.3.** Measure the time difference between the cue appearing in the live feed and its appearance in the streamed video.
Video Quality: **2.** The broadcast should as least be SD quality	**2.1.** Display the streamed video on a remote device capable of showing resolution details. **2.2.** Continuously monitor the displayed resolution to ensure it never drops below SD quality.

2.4. Tolerance Analysis

Our Tolerance analysis focuses on the power subsystem and ensuring that the various voltages required to power different subsystems are within the operating temperature tolerance. We also need to keep in mind that currents provided to the various subsystems do not exceed the datasheet rating of our two voltage regulators. The 3.3 V regulator and 5.0 V regulator both have 150^{o} C. To ensure that the components are thermally safe and if we assume worst case currents, we find the maximum drawn by the HC-SR04 Ultrasonic Transducer is 20 mA while the Raspberry Pi's current draw with the camera on is 350 mA.

If we use the formula $T_{max}=(P_{pi}+P_{UT})*\Theta_{JA}$ where Θ_{JA} is the thermal resistance junction-ambient of the voltage regulator at 50^{o}C/W, we can calculate the worst case temperature below.

$P_{UT} = 5V*20mA = 0.1W$ $\qquad$ $P_{pi} = 5V*350mA = 1.75W$

$$T_{max} = (0.1W+1.75W)*50^{o}C/W = 92.5^{o}C$$

This value is well under the maximum temperature of any L800 series voltage regulator and will be well within the tolerance limits.

Another subsystem that requires mathematical analysis is the motion sensing subsystem. The HC SR-04 uses serial communication for simple data transfer between the microcontroller and the sensor. In our case, we want to detect a bird within a given proximity of the birdhouse. In order to do this we have to use a simple formula to convert the data given into a variable we can use. The HC SR-04 works by returning the time in microseconds of a sound wave. Because we want to convert this time into a calculated distance we need to multiply by the speed of sound in centimeters per microsecond to return a distance in centimeters. Because the sound wave has to travel to the object and back, we also need to divide the total formula by two to get the actual distance. All of these computations are done using code that is then flashed to the microcontroller. An example calculation is shown below for an object that is 20 centimeters away.

$$Travel\,Time = 588.24\ \mu s$$

$$Speed\ of\ Sound = 0.034\ \frac{cm}{\mu s}$$

$$Distance = Travel\,Time * Speed\ of\ Sound = 588.24 * 0.034 = 20\ cm$$

Once the distance is stored as a variable, a simple if then statement can be used to judge if a bird is within the set distance of the feeder, and the control signal can be activated for the video camera to begin recording

3. Ethics and Safety

With a project such as ours, ethics and safety are of the utmost importance for every step of the way. Addressing the ethical concerns there are two main concerns we have identified. First we are concerned that this project has similar products that are already commercially available, which means that we need to actively ensure that we are coming up with unique ideas that are firmly our own. The second ethical concern comes from the fact that there have been other past ECE 445 senior design projects that have similar subsystems to ours, and we want our project to be unquestionably unique. These two problems have similar solutions, and we have identified several ways to ensure that our project is ethically compliant with the IEEE code of ethics, mainly to comply with the tenet of "To uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities." [1].

The physical birdhouse comes with two main safety concerns for our project. The first is water protection for our power system and electronics against inclement weather. This concern is addressed by our water proofing of our enclosure system. The second outdoors related concern is for squirrels and other unintended wildlife from harming the system. This problem is addressed by isolating our bird feeder and protecting all electric components from the environment with adequate security to prevent intrusions.

As a low voltage project, the safety concerns with this project are the same of most typical hardware design labs and we will observe all of the necessary precautions. The main concerns we have for safety in this project is following lab procedures during fabrication and testing. On the user end, the components will be contained in the bird feeder enclosure which means that they should be properly isolated from the electronics and power supply. Because the power supply will be contained within the bird feeder, we will need to make sure that there are no fire hazards in the storage of the supply [2].

The main safeguard we have against copying other products that are on market is to be active in our competitor research rather than being passive. This means we will be actively scouring the internet and other marketplaces for similar products and ensuring that the project we are completing is fully our own unique idea. We will address this during the design process by using our design notebooks to track our own research and creative processes. Tracking these dated and detailed entries will give definitive proof that we actively sought to ensure the individuality of our design process.

Overall, our project's safety and ethical concerns can be minimized and addressed through the use of active prevention techniques and engineering controls to ensure a safe, ethical project for both the fabrication team and the end user.

4. References

- IEEE ethics code

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[2] D. R. Crow and T. M. Crnko, "NFPA 70E," in *IEEE Industry Applications Magazine*, vol. 12, no. 1, pp. 43-49, Jan.-Feb. 2006, doi: 10.1109/MIA.2006.1578564.

- HC SR-04 Datasheet

[3] Hands On Technology, "HC-SR04 Ultrasonic Sensor Module User Guide," HC-SR04 datasheet, (accessed 2/7/2024).

- L7800 Voltage regulators datasheets

[4] STMicroelectronics, "L7800 Series POSITIVE VOLTAGE REGULATORS," L7805 datasheet, Nov. 2004 (accessed 2/7/2024).

- Raspberry Pi Datasheet

[5] "Raspberry Pi 5," 2023. Available: https://datasheets.raspberrypi.com/rpi5/raspberry-pi-5-product-brief.pdf