Automated Wildlife Watcher Proposal

ECE 445 Design Document - Spring 2023

Team #61
Kevin Chen
Xu Gao
Edwin Lu
TA: Mathur Sekar Abhisheka
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1 Introduction

1.1 Problem

Despite interests and concern over climate change and human development, there is actually very little data available about both the diversity and distribution of wildlife insects or avian pollinators. This is especially concerning when considering the myriad number of species that are poorly understood. How many are there? How do they live? What do they eat? What can be done to help further their numbers or have the least negative impact.

It typically takes a lot of time and effort to survey wildlife populations, a more popular approach is to citizen science. By setting up feeding stations or flowering plants in private residences and documenting visiting species, we can gather a more complete picture of the ecological distribution and possible human impact on the local species. But this too is a limited approach as it depends on observers spending time outside and physically observing and document what they saw, a costly and arguably, ineffective method of data collection.

1.2 Solution

We envision a wildlife camera that can keep a certain area of interest not only for a sustained period of time but also can track and follow any wildlife and zoom in for a more clear image or video of their behavior. This not only can relieve time spent for data gathering but also more precise information about suspected wildlife behavior with minimum human presence and interference, as well as some really nice photos and videos.

1.3 Visual Aids

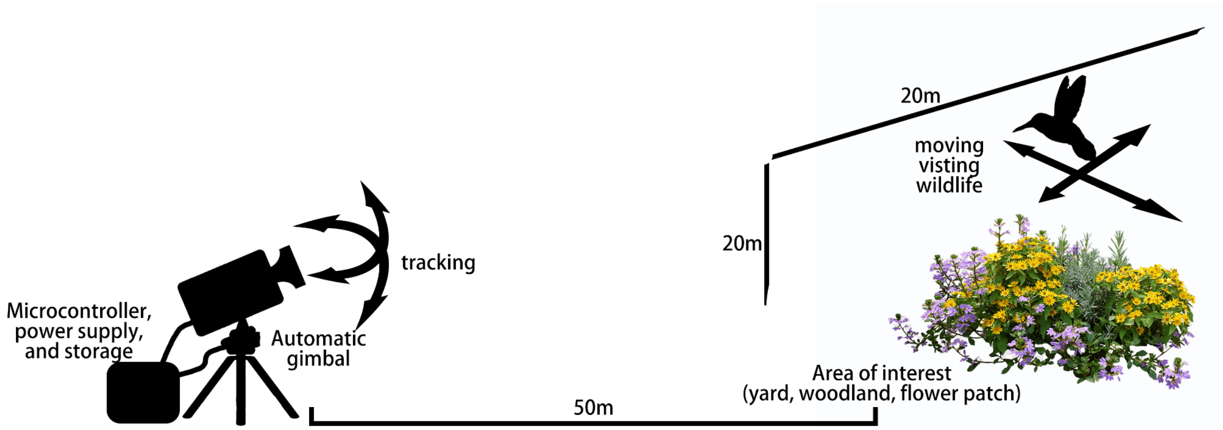

Figure 1: Projected usage of watcher system
Source: Adapted from [1][2][3]

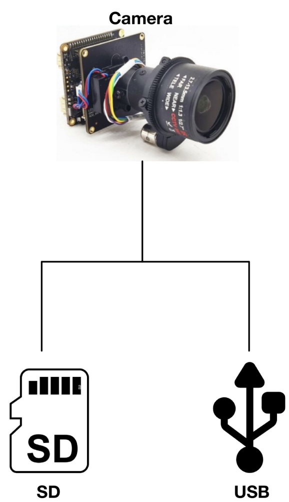

Figure 2: Storage of video and images
Source: Adapted from [4][5]

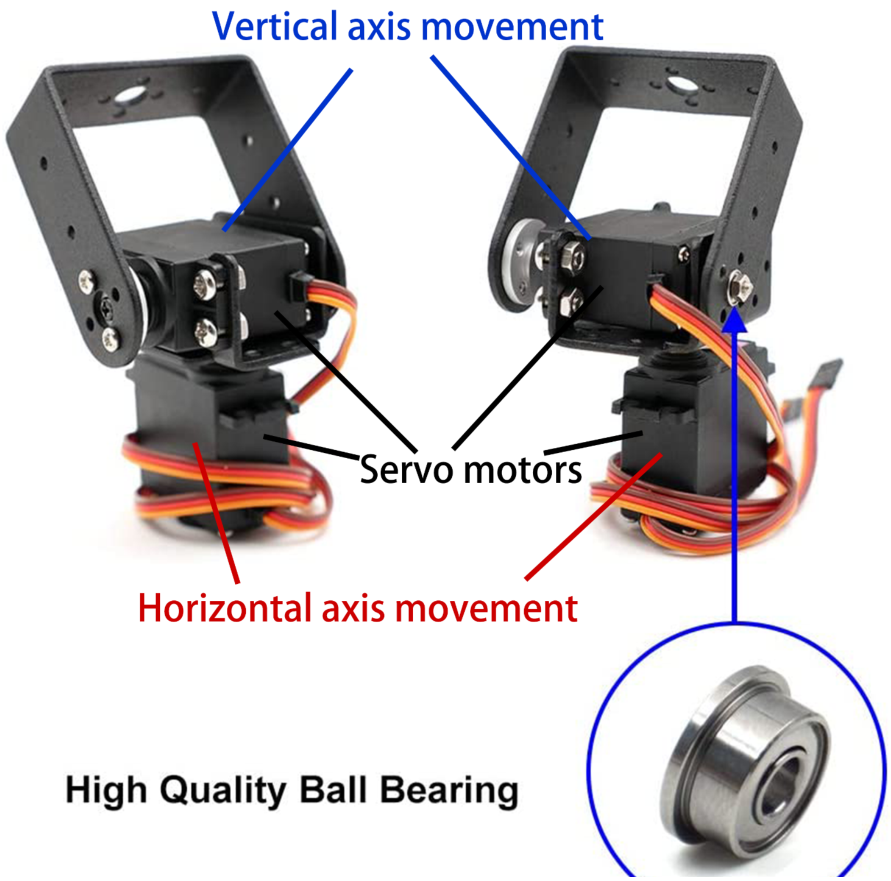

Figure 3: Example gimbal system with servo motors and servo mounts
Sources: Adapted from [8]

1.4 High Level Requirements

- Camera can detect object entering its field of vision
- Gimbal can adjust and track the object that is moving
- The software will zooming the object and capture a photo or video

2 Design

2.1 Block Diagram

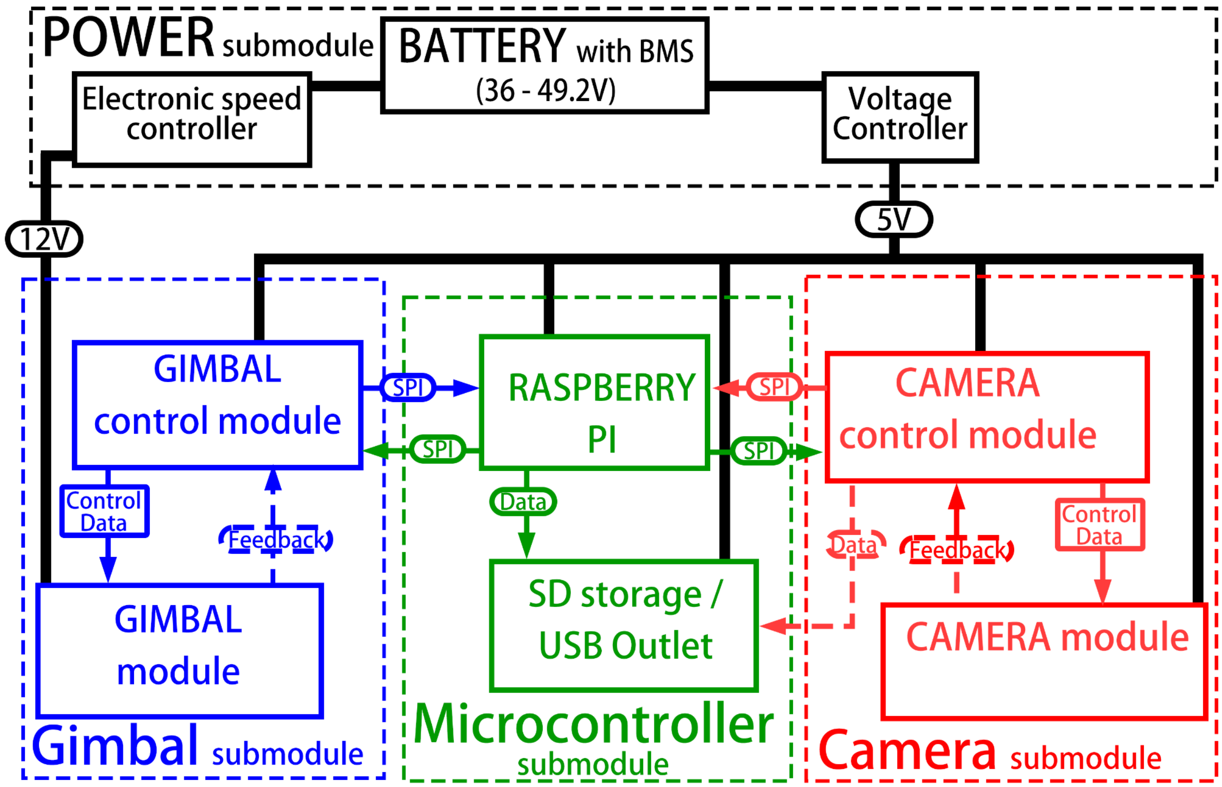

Figure 4: Automated Wildlife Watcher Block Diagram

2.2 Functional Overview & Block Diagram Requirements

2.3.1 Camera Subsystem

The camera module returns in-time videos to the microcontroller. It will watch over the desired location for object and motion detection, align and zoom in certain objects according to signals from the microcontroller, and record and track objects of interest.

Requirements	**Verification**
When the target object is moving in the camera	Throw inanimate objects into view

range, the camera subsystem must detect its motion.	Ensure the camera subsystem can detect objects motion
When the desired sized object (squirrel) is in the camera range, the camera subsystem must recognize it.	Throw objects of different sizes Ensure the camera subsystem can detect them respectively
When the target object is too far or too close to the camera, the camera subsystem must zoom in/out at the proper position.	Learn with training and testing sets Ensure the camera subsystem can zoom and focus properly

Table 1: Camera Subsystem – Requirements & Verification

2.3.2 Gimbal Subsystem

The stepper motor is used to rotate the camera in both the vertically 90 degrees and horizontally 180 degrees. It will support the camera at the designed height to track the target object if it moves within the designed range.

Requirements	**Verification**
When the target object runs out of the camera range, the motors must be prepared for simultaneous movement to keep the object inside the range.	Test the motors independently Ensure the motors are able to move independently
Gimbal can track expected animal movement	Inanimate objects and example training videos

Table 2: Gimbal Subsystem – Requirements & Verification

2.3.3 Microcontroller Subsystem

The microcontroller, chosen to be Raspberry Pi, controls both the gimbal and the camera module. It communicates with the gimbal and the camera module through SPI(Serial Peripheral Interface). The microcontroller subsystem also has a data storage subsystem that allows video and image data to be saved out of the system.

Requirements	**Verification**
When the gimbal needs to move, the microcontroller subsystem must communicate with the gimbal system	Needed controls
When the camera needs to turn on/off, the microcontroller subsystem must communicate	Needed controls

with the camera system	
When the recorded image or video needs to be saved, the microcontroller subsystem must give instruction to store data	Needed subsystem

Table 3: Microcontroller Subsystem – Requirements & Verification

2.3.4 Power Subsystem

A battery pack with BMS will be the primary voltage source. An electronic speed controller is required to control and regulate the speed of the motor in gimbal. A voltage regulator is used to regulate the DC voltages required from the microcontroller and camera modules.

Requirements	**Verification**
When the entire system is operating for hours, the power system must provide sufficient power to each subsystem	Apply stress testing to the power system Ensure the power system is stable enough to support the operation of other subsystems

Table 4: Power Subsystem – Requirements & Verification.

2.4 Hardware Design

2.4.1 Operating Voltage & Regulation

The power system should supply sufficient electric energy to support the operation of the gimbal system and the microcontroller and camera modules. The operating voltage of each part is regulated by the voltage regulator. For the gimbal system, the operating voltage should be at 12V+/- 5%. The operating voltage for the microcontroller and camera modules should be at 5V +/- 5%.

2.4.2 Gimbal System

The gimbal system should provide movement in both the horizontal and vertical axis, to achieve this, a single servo motor (in change of one axis) will be mounted perpendicularly to the mounting tab of another servo motor with a corresponding mounting bracket. Both servo motors will be independently connected to the microcontroller but coordinated to track an object in both axis by the microcontroller. Due to the spatial tolerance (see Section 2.7.1), the gimbal should adjust to 23° horizontally and 22° vertically.

2.5 Software Design

2.5.1 Servo Motor Control

Sufficient control system is needed for the servo motor control. A feedback loop of video data from the camera watching the area for motion detection, control system for recognizing the object of motion then tracking it, then feeding signals to the servo motors for tracking the object.

2.5.2 Moving Object Tracking

The core component of our project is the software moving object tracking of our board microcontroller. It is ultimately responsible for making decisions about calibrating the camera focus and sending signals to the servo motors. To accomplish this, our board microcontroller will take the video from the camera module as an input, and utilize OpenCV package to perform the moving object tracking algorithm.

The possible steps of the algorithm are as follows: Capture frames, Apply motion detection, Apply the Kalman filter to track the object, Compute the object's location.

2.5.3 Object Recognition

Secondary software needed to aid the Tracking software. Once an object has triggered motion in view, the system should be able to recognize the object independent from the background/surrounding and trigger the Tracking software to begin tracking the object across the view. It will use a pre-trained machine learning model available online, like TensorFlow Hub, to perform object (animal) classification.

The software will also be needed for visual capture, it will be needed to adjust the camera subsystem's zoom and focus for a clear, close up view of the object. The recognition software and camera system will adjust accordingly.

2.5.4 Visual Capture

A core component of the project is recording the objects. The visual capture software will be aided by all the mentioned software systems: Object Recognition software, which will determine which object in view is of interest and identify it; the Tracking software, which will track the object across view; the Servo Motor control, which will move and steady the camera for capturing.

The main job of the Visual Capture is to adjust zoom and focus to the object, an open-source software will form the basis of this system.

2.6 Commercial Component Selection

2.6.1 Camera Module

For our camera module, we will be using Arducam 1080P Day & Night Vision USB Camera for Computer. We choose this camera as it can be easily controlled by the raspberry pi and it has Day & Night Vision and high resolution.

2.6.2 Servo Mount Bracket

For our servo mount bracket of the gimbal, we will be using elechawk 2 Sets Pan Tilt Servo Mount Bracket for the MG995 MG996R S3003 Steering Gear Robot Car Boat. We choose this as it can be assembled to a 2 Degree of Freedom gimbal. This satisfies our need to track objects in a 20m*20m*20m space in front of the camera attached to the gimbal.

2.6.3 Servo Motor

For our servo mount of the gimbal, we will be using Servo Motor MG995 Control Angle180 Metal Gear Servo 20KG Digital High Speed Torque Servo Motor for Smart Car Robot Boat RC Helicopter. We choose this motor as it is compatible with our servo mount bracket.

2.6.4 Raspberry pi

As part of our microcontroller, we will be using GeeekPi Raspberry Pi 4 4GB Kit - 32GB Edition. This will help us better communicate with the camera module. And we will write most of our algorithms on the raspberry pi.

2.6.5 Tripod

For our tripod, we will be using qubo Mini Tripod for Camera and Phone. We choose this tripod as it is compatible with our gimbal.

2.6.6 Board Battery & BMS

For our battery, we will be using four AA batteries with a Jex Electronics Four/4X AA Panel Mount DIY Battery Holder Case Box. We choose this as four AA batteries, with the voltage of 6V, are enough to supply our project.

2.7 Tolerance Analysis

2.7.1 Spatial tolerance

The project should have a maximum desired range of 50 meters, where further tolerance requirements should be met.
It should cover an area of 20 meters wide and 20 meters high at maximum.

2.7.2 Object tolerance

The smallest object or animal that can be consistently detected and recognized is a squirrel, 25-45cm (10-18in).
The fastest object that can be consistently detected or tracked is dependent on the speed of the gimbal, which is 0.13s/60° with load.

2.7.3 Time tolerance

Observation of wildlife requires time and patience. The system should be able to run continuously for an hour at least.

2.8 Cost Analysis

Description	Manufacturer	Quantity	Extended Price	Link
Camera	Arducam	1	34.99	link
Servo Mount Bracket	Elechawk	1	12.99	link
Servo Motors	Deegoo-FPV	1 (4)	19.99	link
Raspberry pi	GeeekPi	1	229.99	link
Tripod	QuBona	1	21.95	link
Battery Holder	Jex Electronics	1	2.69	link

Table 5: Itemized list of Components and Costs

2.9 Schedule

Week	**Task**	**Person**
February 27th - March 5th	Order parts for prototyping	Everyone
	Start board assembly	
	Gimbal Prototype	
	Research on gimbal controlling	
March 6th - March 12th	Continue board assembly	Xu
	Continue gimbal prototype	Edwin
	Continue research on gimbal controlling	Kelvin
	Start PCB design & microcontroller assembly	Everyone
March 13th - March 19th	Test gimbal prototype functionality	Edwin
	Continue research on gimbal controlling	Kelvin
	Research on Motion Tracking algorithm	Edwin
	Continue PCB design	Xu
	Continue microcontroller assembly	Everyone
March 20th - March 26th	Test gimbal controlling algorithm with fixed picture	Kelvin
	Continue research on Motion Tracking algorithm	Edwin
	Finish BMS assembly	Xu
	Finish PCB Design & Pass Audit	Everyone
March 27th - April 2nd	Continue motion tracking algorithm	Edwin
	Continue gimbal controlling algorithm	Kelvin
	Revisions to PCB Design	Xu

	PCB ORDER MARCH 28th & 29th	Everyone
April 3rd - April 9th	Finalize motion tracking algorithm	Edwin
	Finalize gimbal controlling algorithm	Kelvin
	Revisions to PCB Design & Finalize hardware parts	Xu
	Start Object Classification Algorithm	Everyone
April 10th - April 16th	Test motion tracking algorithm with real objects	Edwin
	Test gimbal controlling algorithm with generated signals from the microcontroller	Kelvin
	Test & Fix Hardware	Xu
	Test Project Functionality	Everyone
April 17th - April 23rd	Fix Existing Minor Bugs	Everyone
April 24th	Demo	Everyone

Table 6: Schedule for Project Progression

3 Ethics and Safety

3.1 Ethics

As UIUC engineering students, we have read and made ourselves familiar with the IEEE code and ACM code. According to part II in the IEEE code[6], we treat everyone fairly and with respect. This group is open to everyone's ideas and will try our best to avoid injuring others by false actions or any other physical or abuse abuses. In 1.3 of the ACM code[7], we should follow the principle to be honest. Copying other sources without citation is not allowed. In our project, we may use the open source code to help us build our algorithm. We will pay attention to sources used throughout the progress so that every source is cited in documentation. When there are questions or uncertainty related to ethical issues, we will seek help from TAs and professors.

3.2 Safety

Everyone should complete the safety training to obtain lab access. The working schedule will be planned so that no one will work in the lab alone. When there is a case that requires the use of utilizing certain battery chemistries or to work with high voltages, the member should complete additional training.

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