ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Bird-Watching Telescope with Real-Time Bird Identification

Team #14

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1 Introduction

1.1 Problem

When observing wild birds at a distance with a handheld telescope, due to the agility of the birds, before one can carefully identify or record the characteristics of the birds (appearance and call), they often fly away, making it difficult to determine the species. A smart telescope is needed to greatly assist bird watchers, especially beginners, and provide real-time identification of birds.

In addition, the excellent environment surrounding the campus attracts a wide variety of birds, but many students don't realize that they have such a rich natural resource. According to the German Center for Integrative Biodiversity Research, the diversity of birds brings a sense of satisfaction[1]. Therefore, students on our campus need a novice-friendly birdwatching scope to identify and view the different birds on campus, so they can take advantage of the diversity of birds on campus to help them relax outside of their school workload.

1.2 Solution

As the name of our project suggests, our solution consists of two parts, a telescope and camera to observe and record birds, and software to recognize bird species. In order for the two parts to work together, we need to implement a set of control units for data communication between them. As we expect, we will use the camera module with a set of lenses in front of it, similar in structure to a monocular, to realize the function of magnification. At the same time, the distance between certain lenses will be controlled by stepper motors as well as the corresponding mechanical structure, and the side of the telescope will pretend a laser ranging module and measure the distance between the telescope and the observed bird. The control unit is a microcontroller computer with remote communication capabilities, connected to a monitor. It is connected to the stepper motors and the laser ranging module by wires, receives and processes the distance data and controls the stepper motors to adjust the lens in order to focus. In addition, it is remotely connected to a cell phone, and once connected, the built-in software will automatically control the camera to record video and transmit the footage to the software in the cell phone that identifies the bird species. The software will use an artificial intelligence model to recognize the species of bird present in the video and transmit it through to the control unit and display it on the screen.

1.3 Visual Aid

Figure 1: Visual aid.

1.4 High-level requirements list

- The accuracy of bird identification should be at least 80%.

- The time bird identification process should be less than 3 seconds.

- The telescope should be able to record clear videos of birds within 20 meters.

2 Design

2.1 Block Diagram

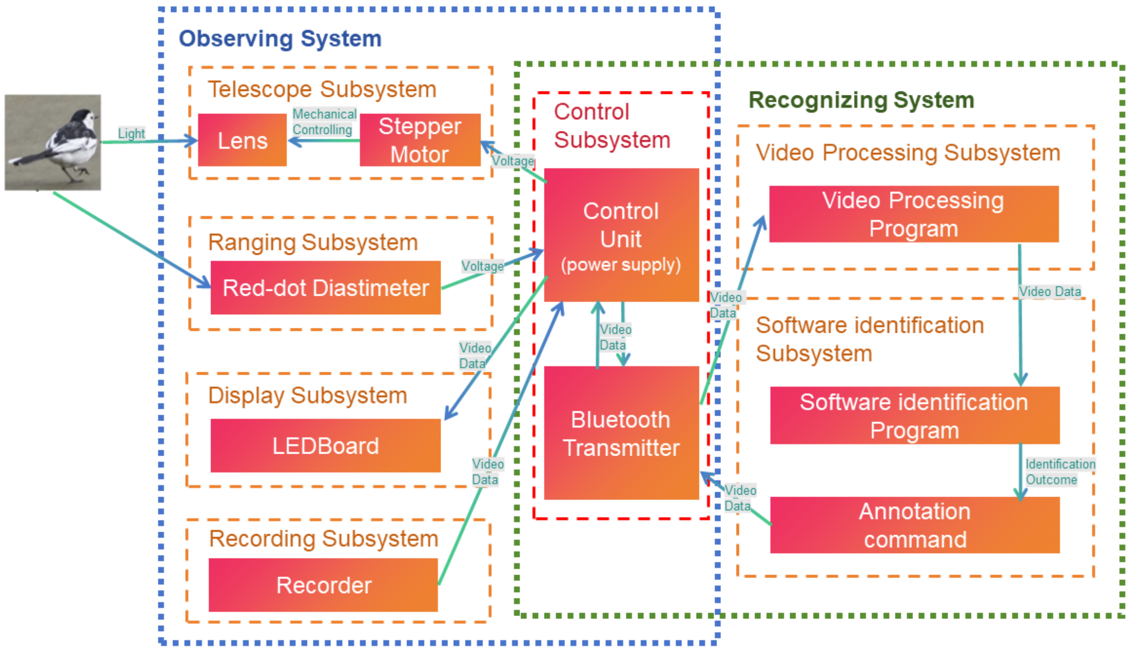

Figure 2: Block Diagram.

2.2 Subsystem Overview

2.2.1 Observing System

Recording Subsystem:

1. **Overview**: The recording subsystem is a portable camera, which would capture the video behind the ocular. It would transmit the video data to the controlling subsystem, the Raspberry Pi, with data link, and later transmit to software identification subsystem for later identification.

2. **Requirements**: The recording resolution should be high enough for later identification in software identification subsystem, in order to make sure of the identification accuracy. And it should have basic functions of automatically adjust the camera to adapt to the environment luminance, and focus on the frame through the telescope subsystem. The distance between camera and ocular should be carefully adjusted when designing the spatial arrangement.

3. **Tolerance Analysis**: The resolution for small camera which can do the recording task now is good enough and very cheap, compared with those several years ago. Also, the transmitting speed is quick enough for later works. We found that there

have been many electronic eyepiece wireless camera in the market, with high solution of nearly 200W. So it should be fine.

Telescope Subsystem:

1. **Overview**: The telescope subsystem is used to magnify the image of the observed bird and project it to the camera subsystem. At the same time it will receive focus adjustments from the control subsystem.

2. **Requirements**: The lens set is used to magnify the target image. Therefore the image of the lens set must be clear and have sufficient magnification. Stepper motors are used for auto-focus, which mechanically connects the lens to realize the movement of the lens. The design of this mechanism requires a small error to ensure accurate focusing. Otherwise the camera subsystem will not be able to output clear video, resulting in the identification system not working.

3. **Tolerance Analysis**Due to the lack of understanding of optics, the design of our telescopes had to rely on reverse analysis of market products and consultation with professionals, which added to the difficulty of completing the project. Regarding feasibility, since telescopes were invented as early as the sixteenth century and the autofocus function was realized long ago in the 1980s, these designs are fully achievable.

Ranging Subsystem:

1. **Overview**: Used to measure the distance between the lens and the observed bird, transmitting the data to a Raspberry Pi for automated focusing of the mechanical structure.

2. **Requirements**: Parallel to the telescope to ensure the infrared ranging position is precisely on the bird without tilting; powered by the Raspberry Pi with appropriate power to avoid harming observed birds or users' eyes, yet ensuring accurate ranging even for distant birds to avoid signal scattering due to low power; needs built-in drivers to transmit distance data to the Raspberry Pi.

3. **Tolerance Analysis**: Structurally simple, akin to a rifle's infrared sight, collecting positional distance information.

Display Subsystem:

1. **Overview**: The display subsystem is to show the result of the identification from software identification subsystem on mobile phone. An LED would show the videos annotated with colored frames annotating where the bird is and what its species is and the corresponding accuracy of the identification.

2. **Requirements**: The display LED board should have high resolution in order to show the original views of the video. The delay should be short enough so the user experience would not be ruined.

3. **Tolerance Analysis**: The resolution might not be high enough. The usage experience would be strongly related to the timeliness of displaying the result on the

LED board. The delay should be depend on the recording system, preprocessing, transmission speed, and especially the identification part on mobile phone.

2.2.2 Recognizing System

Video Processing Subsystem:

1. **Overview**: The Video Processing subsystem will simply preprocess the videos on telescope in Raspberry Pi, making it suitable for Bluetooth transmission.
2. **Requirements**: It should be quick enough, and preprocess the video to compress the video to a suitable format, which satisfies both timeliness and accuracy.

Software Identification Subsystem:

1. **Overview**: This subsystem is responsible for processing the video from the telescope and identifying the birds in the video. It processes video feeds from telescopes, capturing and enhancing footage to extract individual frames.
2. **Requirement**: This subsystem utilizes the YOLO (You Only Look Once) object detection algorithm, aiming to achieve high accuracy in identifying various bird species within video frames. The system begins with frame extraction to isolate individual frames for analysis, followed by preprocessing steps such as resizing and standardization to ensure uniformity and compatibility with the YOLO model. YOLO is then employed for bird detection, with further model configuration and optimization to enhance accuracy and minimize false positives. Through rigorous evaluation, the subsystem strives to achieve a minimum accuracy of 90% in bird identification, with a stringent maximum false positive rate of 5%.
3. **Tolerance Analysis**: The identification process may not be quick enough since process a real-time video is hard, and we still need to transmit the video and result back and forth between the devices. When the bird flies away too quickly before the identification could be done, the LED will not have the chance to annotate. We may choose a second plan. We could have the video with the bird stored in mobile phone, list out the corresponding identification result on phone, which could be later checked on phone.

2.2.3 Control Subsystem

1. **Overview**: The control system includes a Raspberry Pi, which would provide power and act as the controller for some simple processing, with a Bluetooth USB transmitter connected. The control subsystem will transmit the video data to mobile phone, and get the identification result back with annotations for bird species and accuracy. Then the subsystem should convey the data to LED for display. Also, for the automatic focusing, control subsystem will help process the distance range and send command to stepper motors to adjust the focus onto the bird.
2. **Requirements**: Raspberry Pi Fifth Flagship Development Computer is assembled

with a powerful 2.4GHz 64-bit quad-core Arm processor and an 800MHz VideoCore VII GPU for impressive graphics. It offers advanced camera support, versatile connectivity, and enhanced peripherals, perfect for multimedia, gaming, and industrial tasks[2].
And the Bluetooth USB transmitter should accept at least Bluetooth Core v5.0, since new Bluetooth protocol would serve a better speed and bandwidth. Here lossless audio source transmission at 24bit/192KHz is supported[3]. And most products on markets are using Bluetooth Core v5.0. This would mostly satisfy our needs.

3. **Tolerance Analysis**: The hashrate may not be enough for all the processes to be done on telescope. And Bluetooth transmission may be disturbed in certain environments.

3 Ethics and Safety

3.1 Ethics

3.1.1 Privacy Protection

Ensure that user data, including images and location information, is collected and stored securely. Obtain informed consent from users before collecting any personally identifiable information. Implement strict protocols for data handling and adhere to relevant privacy laws and regulations.

3.1.2 Bias Mitigation

Train the AI bird recognition system on diverse datasets to mitigate biases based on species, gender, age, and environmental conditions. Conduct regular audits and evaluations to identify and address any biases in the recognition algorithms. Transparency in the algorithm's decision-making process to ensure fairness and accountability.

3.1.3 Ethical Treatment of Birds

Promote ethical birdwatching practices among users, including maintaining a respectful distance from nesting sites and minimizing disturbance to birds. Encourage users to contribute to conservation efforts and follow established codes of conduct for birdwatchers.Educate users about the importance of preserving natural habitats and respecting wildlife.

3.1.4 Community Engagement

Engage with local communities and stakeholders to gather feedback and ensure alignment with community values and priorities. Foster collaboration and knowledge sharing among users to promote a culture of responsible birdwatching and environmental stewardship. Address any concerns or ethical dilemmas raised by stakeholders through open communication and dialogue.

3.1.5 Species Protection

Revealing the locations of rare birds could potentially attract poachers, posing a serious threat to these species' survival. Additionally, the influx of birdwatchers drawn to these sites might disturb the natural habitat and behaviors of the birds, negatively impacting their breeding and feeding patterns. It's crucial to balance the enthusiasm for birdwatching with the need to protect and preserve wildlife and their environments.

3.2 Safety

3.2.1 User Safety Guidelines

Provide comprehensive instructions for safe use of the equipment, including handling optical lenses and other potentially hazardous components. Warn users about potential risks associated with birdwatching activities, such as encountering aggressive birds, navigating uneven terrain, or adverse weather conditions.

3.2.2 Environmental Impact Assessment

Evaluate the environmental impact of deploying the bird recognition tool, including energy consumption and disposal of hardware components. Promote awareness among users about the impact of human activities on bird habitats and ecosystems, encouraging responsible behavior. Encourage eco-friendly practices, such as minimizing carbon footprint and reducing waste generation, during fieldwork and data collection activities

References

[1] German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig. "Biological diversity evokes happiness." Accessed: 2020-12-04. (Dec. 2020), [Online]. Available: https://www.sciencedaily.com/releases/2020/12/201204110246.htm.

[2] Raspberry Pi Foundation, *Raspberry Pi 5*, https://www.raspberrypi.com/products/raspberry-pi-5/, Accessed: 2024-03-11, 2024.

[3] M. Woolley, *Bluetooth® Core Specification Version 5.0 Feature Enhancements*, https://www.bluetooth.com/wp-content/uploads/2019/03/Bluetooth_5-FINAL.pdf, Accessed: 2024-03-11, Sep. 2021.