Bird Box

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1. Introduction

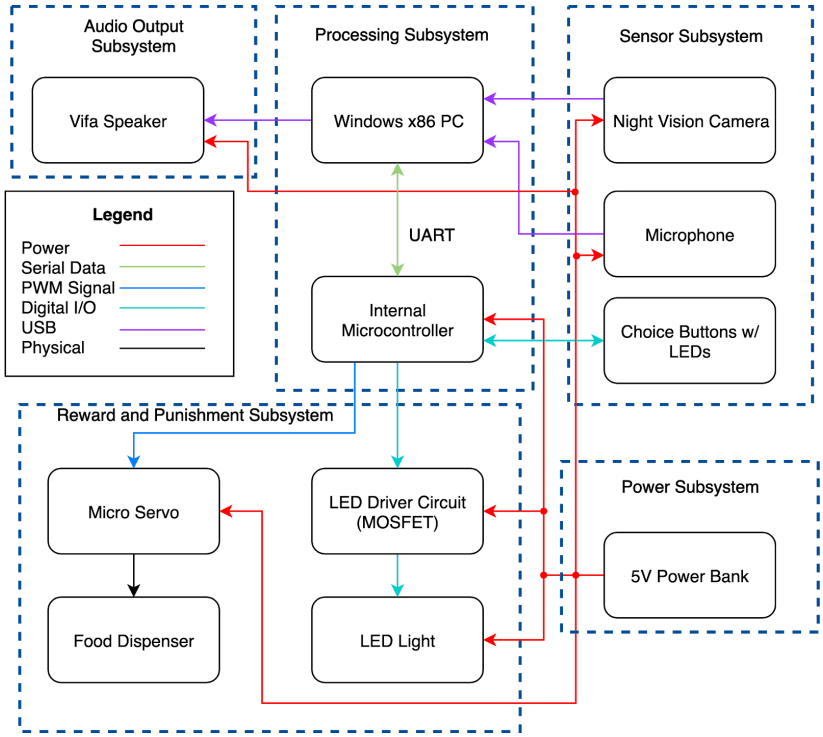
- **Objective**: Birds communicate with each other with different sounds and frequencies. Sometimes they have similar responses to different sounds. Other times, researchers can only understand what the birds hear by observing the surrounding environment. Researchers need better ways to know what can a bird actually hear and what frequencies it can distinguish.
  Our solution for determining what the birds can hear is to create a bird box. The bird box is a container that has a speaker to play test sounds, choice buttons for birds to make choices when responding to the test sounds, camera to monitor the bird, a food reward dispenser when the bird makes the correct choice, and a light to be turned off for punishment. The box can also be controlled by an automated computer program that runs trials autonomously. The bird box can provide an ideal experiment environment for researchers to test the bird's ability to recognize sounds.

- **Background**: Songbirds communicate with each other through different songs. They can hear and discriminate among different songs as well as produce them. The study on what kind of songs can songbirds recognize and discriminate is very important. Previous researches and methods prove that positive reinforcement is an effective way to test the songbirds. Computer-based test apparatuses were used in some of the research, and our goal is to make a similar but improved apparatus to aid the researchers in the study of songbirds.

- **High-level requirements list:**
  i. When the bird performs the correct task, the bird box should give food reward to the bird as the positive reinforcement.
  ii. When the bird performs the wrong task, the bird box should turn off the light as negative punishment.
  iii. When the bird does not interact with the box for a long period of time defined by the experimenter, the bird box should warn the experimenter.

2. Design

- **Block Diagram**:



The high-level design of the bird box contains five modular subsystems, which are the audio output subsystem, the processing subsystem, the sensor subsystem, the reward and punishment subsystem, and power subsystem. The audio output subsystem plays test sounds. The processing subsystem reads the sensor inputs, plays the test sound to the output devices, and runs the experiment program. The sensor subsystem collects the bird's voice and video as serves as the input device for birds during the experiment. The reward and punishment subsystem uses reinforcement learning to teach the bird how to interact with the bird box. The power subsystem provides 5V power for all the other subsystems. The design will satisfy the high-level requirements as the sensor subsystem would provide data on whether the bird does the right thing or not, and the reward and punishment subsystem will reinforce the learning.

- **Physical Design:**

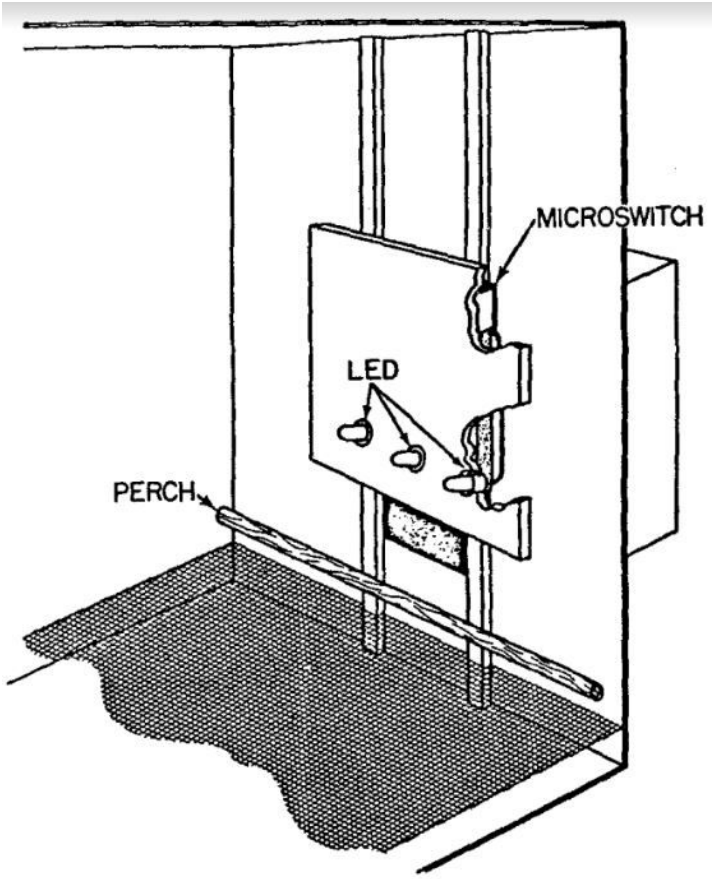


Figure 1: Park, Thomas, "Operant Conditioning of Small Birds for Acoustic Discrimination"[1]

The physical design of the bird box is inspired by the design of the above diagram of the apparatus used in "Operant Conditioning of Small Birds for Acoustic Discrimination" (Park, Okanoya & Dooling, 1985). Our design will use microswitches as the choice buttons for birds because the birds we will be testing with would not have enough force to push larger switches. The microswitches would also have LEDs on them so that birds can get visual cues when pecking the microswitches. They will have a perch to rest on. The food dispenser will be mounted closely to the microswitches so the birds can get feedback immediately after they perform the right tasks. The light, speaker, camera, microphone, and other components will be placed on top or on other sides of the cage.

- **Functional Overview:**
    i. Audio Output Subsystem: The audio output subsystem only includes the speaker. Since we will be testing the acoustic discrimination on birds, we need a speaker to play the test sounds. The speaker will be connected to

a Windows x86 PC's audio jack, and the PC will provide the audio output. The power subsystem will provide power through USB.

ii. Processing Subsystem: The processing subsystem contains two parts, the Windows x86 PC and the microcontroller. All USB sensors from the sensor subsystem as well as the audio output subsystem will be connected to the PC. And all digital I/O sensors and outputs (microswitches and LEDs) will be connected to the microcontroller. The microcontroller communicates with the PC through the UART serial. A USB-UART converter handles the conversion between USB and UART. The processing subsystem runs the experiment program, processes all data from the inputs, and stores the experiment data.

iii. Sensor Subsystem: The sensor subsystem includes the camera, microphone, and choice buttons. The camera and the microphone would be connected to the Windows x86 PC under the processing subsystem. The choice buttons include two parts: the microswitches and the LEDs. One indicator LED will be attached directly to the microswitch as visual feedback for birds. The choice buttons will interface with the microcontroller under the processing subsystem through digital I/O. The sensor subsystem provides necessary input for the experiment to run autonomously and also gives experimenters feedback on birds.

iv. Reward and Punishment Subsystem: The reward and punishment subsystem consists of the food dispenser and the LED light bulb. In order to make the bird learn how to interact with the bird box through reinforcement learning, the subsystem gives reward when the bird performs the right task and gives punishment when the bird performs the wrong task. The reward is to give food to the bird, and the punishment is to annoy the bird by turning off the LED light bulb for a short period of time. The processing subsystem controls the reward and punishment subsystem by the digital I/O.

v. Power Subsystem: The ideal power subsystem for this design would be just the USB port from the x86 PC. However, the port may not have a high enough power rating. In this case, a 5V power bank or a USB charger would be sufficient. The power subsystem provides 5V through the USB to all other subsystems.

- **Block Requirements**
  i. Audio Output Subsystem
     1. The speaker's frequency response must be able to cover all the test sounds' frequencies.

2. The speaker must be able to output sound from the analog input with low latency.

ii. Processing Subsystem
    1. The microcontroller must be able to handle inputs from birds no slower than the frequency of the bird pecks.
    2. The UART serial, communication protocol, and real-time software must ensure that the whole control loop is fast enough for reinforcement learning.
    3. The microcontroller must not activate the punishment system when it loses connection with the PC.
    4. The user software should be able to autonomously run the full experiment in normal circumstances.
    5. The user software on PC should be able to record all the relevant data for easier access by the experimenters.
    6. The experimenters should have the highest privilege than all the autonomous programs when interacting with the reward and punishment system.

iii. Sensor Subsystem
    1. The experimenter should be able to see the birds through the camera in low-light conditions.
    2. The experimenter should be able to hear the birds during the experiment through the microphone.
    3. The microswitches' operating force should be lower than the normal force of a bird's peck.
    4. The indicator LED should be able to toggle faster than the frequencies of the bird's pecks.
    5. The microswitches should be debounced.
    6. When the user switches the plugs of the indicator LED and the microswitches, the circuit should not be damaged.

iv. Reward and Punishment Subsystem
    1. The food reward dispenser must be able to give food rewards to birds reliably.
    2. The punishment subsystem must be able to switch the LED light bulb on and off.
    3. The food reward dispenser should be safe for birds even when the birds try to get food through other ways.

v. Power Subsystem
    1. The power subsystem must be able to provide a voltage of 5-5.5V for a current load up to 2A.

2. The power subsystem must be able to either charge from or convert 120V AC voltage to 5V DC.

- **Risk Analysis**: The food reward dispenser under the reward and punishment subsystem poses the greatest risk to the successful completion of the project. The food dispenser is critical to the success of the experiment because the bird will likely not cooperate without food reward. However, the operation of such a food reward dispenser relies heavily on mechanical design, and we could not find available products from other sources.

3. Ethics and Safety

- Due to the usage of the bird box, there are concerns about the safety of the bird when experiment trials are being conducted.
    i. Since birds are more vulnerable than humans, most of the components in our project, if broken, pose some potential danger to birds. We will put delicate parts of our projects such as the camera and microphone out of the reach of the birds. If the part has to be within the reach of the birds, it will be behind a piece of acrylic panel (Plexiglass).
    ii. Because of the nature of the project, we have to include a food reward dispenser with moving parts in the bird box. Considering the safety of the bird, the dispenser will move at a slow pace to allow the birds to dodge the moving dispenser.
    iii. Since we are "punishing" the birds for performing the wrong task as negative punishment, it is important to keep the birds safe during the "punishment". We will use a very gentle "punishment", which is to turn off the lights for a short period of time. This will annoy the birds but not do any actual damage. However, a human experimenter is required to monitor the birds during the experiment in case of any emergencies.
- We would potentially go against #1.2 in the ACM Code of Ethics[2] and #1 in the IEEE Code of Ethics [3] because we would have to create negative consequences when the birds do the wrong task. However, we will try our best to minimize the discomfort of birds by turning off the lights for the shortest period of time possible while still being able to achieve the effects of negative punishment.
- Other parts of the bird box should be complying with #1 in the IEEE Code of Ethics[3]. All the components in the bird box would be safe to the experimenters under normal use conditions.
- The bird box and its use protocol is approved by the Institutional Animal Care and Use Committee (IACUC) and the approval is valid through 4/2/2021 [4]. We would work closely with the researchers and experimenters to ensure that the design of the bird box would be safe under the use protocol.

Citation

1. Park, T., Okanoya, K. and Dooling, R. (1985). Operant conditioning of small birds for acoustic discrimination. Journal of Ethology, 3(1), pp.5-9.
2. Acm.org. (2019). ACM Code of Ethics and Professional Conduct. [online] Available at: https://www.acm.org/code-of-ethics [Accessed 19 Sep. 2019].
3. Ieee.org. (2019). IEEE Code of Ethics. [online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 19 Sep. 2019].
4. Approval of Animal Use Protocol. (2018). Institutional Animal Care and Use Committee. [Accessed 19 Sep. 2019].