Introduction
Team 48
Electrochromic Bird-Friendly Windows

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Problem

- Approximately one billion fatal bird-window collision in America each year
- Current solutions significantly compromise visibility/aesthetic appeal → Adoption is low
- Conservation concern
Problem

Sources of bird mortality in the United States

mongabay.com

Window collisions | Domestic cats | Hunting | Vehicular collisions | Wind turbines
Objective

To lower the rate of fatal bird-window collisions in an efficient manner while keeping the aesthetic appeal of the window
Solution Design
Initial Idea

- Need to make birds aware of the hazard
  --> Make window visible
  --> Electrochromic Materials
- Detect Birds approaching and change opacity
Initial Idea

- Use ultrasonic sensors to detect birds approaching
- Change opacity of electrochromic panels when a bird is detected
Design Revision

- Fast flight speed and slow reaction time -> adjusted dimensions
- Aesthetically unappealing -> use hollow frame
- Can’t distinguish between birds and rain, leaves, etc. -> add image processing
Design Revision

- Insufficient number of pins on microcontroller -> decrease sensors to minimum number necessary
- Limited field of vision -> move thermal camera to frame’s center
Image Processing

1. Object Detected?
   - Yes: Capture a thermal image
   - No: Start tracking warm-blooded object

2. Within the region of object detection, is there a blob within our desired temperature and size ranges?
   - Yes: Are we currently tracking a warm-blooded object?
     - Yes: Stop tracking warm-blooded object
     - No: Are we currently tracking a warm-blooded object?
       - Yes: Stop tracking warm-blooded object
       - No: Start tracking warm-blooded object
   - No: Within the region of object detection, is there a blob within our desired temperature and size ranges?
Design continued

- POWER SUBSYSTEM
- CONTROLS SUBSYSTEM
- OBJECT CLASSIFICATION SUBSYSTEM
- OBJECT DETECTION SUBSYSTEM
- BIRD INTERFACE
Design continued
High Level Requirements
High Level Requirements

When the system is at rest the panels must be kept in their transparent state. The system is considered at rest before a bird is detected or after a bird has exited.
High Level Requirements

The system must be able to successfully detect an object traveling at 7.6 m/s or less of length ≥ 11 cm and width ≥ 19 cm (minimum length and wingspan of the seven birds with the highest rates of window collisions) entering or exiting through the front of the 24 x 24 x 58 cm rectangular prism encompassed by the frame in ≥ 80% of trials.
High Level Requirements

When the system determines that an object has been detected entering the frame-encompassed area, it must successfully transition one or more of the electrochromic panels from transparent to opaque.
Assumptions

- Majority head-on collisions
- One bird at a time
- Semi-species specific
  - White-throated Sparrow
  - Ovenbird
  - Common Yellowthroat
  - Dark-eyed Junco
  - Brown Creeper
  - Hermit Thrush
  - Black-and-white Warbler
Successes & Challenges
Challenges

- Physical design compromise
- High current draw from panels
- Ultrasonic sensor accuracy
- Microcontroller malfunction/switch to Arduino (less pins)
- Improvised digital switches
- Arduino limited current draw
- Not enough parts
- Integration
Successes

- Sturdy, portable, clean-cut frame
- Included DC/AC converters (altered parameters)
- Fast Ultrasonic Sensor/Microcontroller Response Time (7.85 m/s)
- Consistent detection under 58 cm (≥ 80% of trials)
- Full and location-specific panel transitions
- Accurate image processing/object tracking
- No panel damage
Results
### Interface

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Curf1</td>
<td>4.000 ms</td>
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<tr>
<td>Curf2</td>
<td>4.000 ms</td>
</tr>
<tr>
<td>Delta</td>
<td>0.000 s</td>
</tr>
<tr>
<td>ΔV</td>
<td>0.000 V</td>
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**Input and Output**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Period</td>
<td>--</td>
</tr>
<tr>
<td>Frequency</td>
<td>--</td>
</tr>
<tr>
<td>Peak peak</td>
<td>7.712 V</td>
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<tr>
<td>Peak-peak</td>
<td>183.683 mV</td>
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<tr>
<td>Mean</td>
<td>251.507 mV</td>
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<tr>
<td>Mean</td>
<td>2.934 V</td>
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**Waveform**

- **Sampling Rate**: 600,000 μs/div
- **Sample Rate**: 8000 at 1 Msps

**DC/AC Converter Input and Output**
Detection/Interface
## Performance: Ultrasonic Sensors

<table>
<thead>
<tr>
<th>Ultrasonic Sensor 3</th>
<th>Ultrasound Sensor 4</th>
<th>Ultrasonic Sensor 5</th>
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<td>Ruler-Measured</td>
<td>Sensor-Measured</td>
<td>Distance</td>
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<td>Sensor-Measured</td>
<td>Distance</td>
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### Ultrasonic Sensor Accuracy (cm)
Results: Classification
Conclusions & Takeaways

- Order many, many spare parts as early as possible
- Datasheet accuracy varies
- Make accountability a habit early on
- Unit test in short bursts
- Has potential for larger applications
Recommendations

- Economies of scale -> increase application size
- Testing with live birds
- Waterproof system for field applications
- Adapt parameters based on geographical location (temperature, threshold)
- Implement more efficient image processing algorithm
- Median Filter
Questions?
Appendix
Block requirements: Control Subsystem

- The control subsystem must be able to calculate distances correctly based on input from the ultrasonic sensors. For measured distances below 20 cm, the accuracy of the calculated distances should be within 5 cm. For measured distances between 20-100 cm, the accuracy of the calculated distances should be within 10 cm.

- The control subsystem must be able to signal to the electrochromic panels to change opacity once an object is detected. I/O pins controlling the opacity should transition to a high voltage (2.7-5.5 V) in 95% of trials.

- The control system must be able to initiate image processing in the Raspberry Pi. The interrupt pin of the microcontroller feeding into the Raspberry Pi must go high (2.7-5.5 V) when an object is detected in 95% of trials.
Block requirements, Object Detection and Object Classification Subsystem

Object Detection

- For measured distances below 20 cm, the accuracy of the calculated distances should be within 5 cm in ≥95% of trials. For measured distances between 20-100 cm, the accuracy of the calculated distances should be within 10 cm in ≥95% of trials.
- The ultrasonic sensors must be mounted on the frame in such a way that they can accurately determine which electrochromic panel zones the detected objects are entering/exiting within the 3D frame area in ≥95% of trials.

Object Classification

- The image processing can correctly identify warm blooded objects within the 58 cm x 58 cm x 92 cm frame space in ≥85% of trials.
Block requirements: Bird Interface and Power subsystems

**Bird Interface**

- The opacity must visibly transition between transparent and opaque in response to the microcontroller.

**Power subsystem**

- The opacity must visibly transition between transparent and opaque in response to the microcontroller.
- The voltage regulator must supply a DC input voltage 2.5-3.5V to the DC to AC converters feeding into the electrochromic panels at all times the system is operating.