Remote Monitoring of Birds and Bats with Visual and Infrared Stereo Imagery

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Department of Biology
Motivation: Offshore Wind

Carcass counts?

Observer...

So how?
Detection Methods

Transects
Tracking
Acoustic
RADAR
Optical
Evaluating near-field optical systems

<table>
<thead>
<tr>
<th></th>
<th>Temporal Availability</th>
<th>Spatial Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>~</td>
<td>?</td>
</tr>
<tr>
<td>Thermal</td>
<td>+</td>
<td>?</td>
</tr>
</tbody>
</table>

Availability

Temporal availability

Spatial coverage
Evaluating near-field optical systems

<table>
<thead>
<tr>
<th>Feature</th>
<th>Visual</th>
<th>Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal Availability</td>
<td>~</td>
<td>+</td>
</tr>
<tr>
<td>Spatial Coverage</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Cost</td>
<td>$</td>
<td>$$$</td>
</tr>
<tr>
<td>Computation Demand</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Hardware</td>
<td>~</td>
<td>~</td>
</tr>
</tbody>
</table>

**Practicality**

Computational Demand

<table>
<thead>
<tr>
<th>Storage</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Storage Image]</td>
<td>![Processing Image]</td>
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</table>
**Evaluating near-field optical systems**

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<th>Spatial Coverage</th>
<th>Cost</th>
<th>Computation Demand</th>
<th>Hardware</th>
<th>Detection</th>
<th>Behavior Analysis</th>
<th>Species Identification</th>
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<tr>
<td><strong>Thermal</strong></td>
<td>+</td>
<td>?</td>
<td>$$$</td>
<td>?</td>
<td>~</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

**Effectiveness**

Increasing **resolution** requirement

Detection: Is something there?  
Behavior: What is it doing?  
Identification: What is it?  

At what **range**?
Evaluating near-field optical systems

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Stereo?
Improving Computational Demand

**Problem:** Continuous stereo IR + visual generates **20 TB Data/day**

**Solution:** Event based trigger of data recording

Save data 10 s before to 10 s after trigger event to permanent file.
The Optical Node

- Visual
- Infrared
- 1G Ethernet switch
- Power distribution

On turbine pan and tilt mount

Travel profile
## System specifications

<table>
<thead>
<tr>
<th></th>
<th>Thermal Infrared</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>FLIR A615sc</td>
<td>Manta G-210</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>640 x 480</td>
<td>1624 x 1234</td>
</tr>
<tr>
<td><strong>Lens FOV</strong></td>
<td>15° x 12°</td>
<td>52° x 45°</td>
</tr>
<tr>
<td><strong>Frame rate</strong></td>
<td>50 fps</td>
<td>12 fps</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>0.25 Gbps</td>
<td>~ 1 Gbps</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>1 Gbit Ethernet</td>
<td>1 Gbit Ethernet</td>
</tr>
<tr>
<td><strong>Trigger</strong></td>
<td>Software</td>
<td>Hardware</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>~ $ 20 k</td>
<td>~ $ 3 k</td>
</tr>
</tbody>
</table>

Software Infrastructure: **Labview**
Data Collection

SIZE

RANGE

100 m

Marbled murrelet
Pigeon guillemot
Rhinoceros auklet
Barn swallow
Cliff swallow
Bats

Caspian tern

Glaucous winged Heermans Gull

Great blue heron
Pelagic cormorant
Turkey vulture

Short tailed albatross
Field Setup

Command station
- Optical node controls
- Bird meta-data entry

Voucher DSLR
Optical Node

Me
Rob Suryan, OSU
Observers
Stereo Calibration

Camera Calibration Toolbox for Matlab
Jean-Yves Bougout, Caltech
Analyzing Stereo Data

Selecting points in the images

\[ P_{1,L}(x,y) \]
\[ P_{1,R}(x,y) \]

\[ P_{2,L}(x,y) \]
\[ P_{2,R}(x,y) \]
Analyzing Stereo Data

Converting points to real world data

Pixel

\[
\begin{bmatrix}
P_{1,L}(x,y) \\
P_{1,R}(x,y) \\
P_{2,L}(x,y) \\
P_{2,R}(x,y)
\end{bmatrix}
\]

Stereo Triangulation Transformation

Real Positions

\[
\begin{bmatrix}
P_1(x,y,z) \\
P_2(x,y,z)
\end{bmatrix}
\]

Real Position

\[
P_1(x,y,z)
\]

Displacement between frames

Displacement within frames

Velocity

Length
**Tennis Balls: Test of Accuracy**

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity</td>
<td>7.4 m/s</td>
<td>2.7 m/s</td>
</tr>
<tr>
<td>Length</td>
<td>7.9 cm</td>
<td>2.3 cm</td>
</tr>
<tr>
<td><strong>Test 11</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity</td>
<td>11.6 m/s</td>
<td>0.41 m/s</td>
</tr>
<tr>
<td>Length</td>
<td>7.4 cm</td>
<td>4 cm</td>
</tr>
</tbody>
</table>

**Regulation Tennis Ball Size:** 6.3 cm
**Bats**

- **Frame Rate:** 50 fps

---

**Track 1**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>14.5 m</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Velocity</td>
<td>7.14 m/s</td>
<td>2.28 m/s</td>
</tr>
<tr>
<td>Length</td>
<td>14.5 cm</td>
<td>0.03 cm</td>
</tr>
</tbody>
</table>

**Track 2**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>14.6 m</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Velocity</td>
<td>12.2 m/s</td>
<td>4.6 m/s</td>
</tr>
<tr>
<td>Length</td>
<td>14.2 cm</td>
<td>5 cm</td>
</tr>
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</table>
Birds

Frame 82

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
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</thead>
<tbody>
<tr>
<td>Z</td>
<td>81.4 m</td>
<td>17.2 m</td>
</tr>
<tr>
<td>Velocity</td>
<td>31.2 m/s</td>
<td>7.5 m/s</td>
</tr>
<tr>
<td>Length</td>
<td>7.2 cm</td>
<td>3.3 cm</td>
</tr>
</tbody>
</table>

Brewers blackbird
Actual size: 20 – 26 cm

Frame Rate: 12 fps
Conclusions

Strengths:
- Detection
- Temporal Availability
- Automatic Processing

Weaknesses:
- Cost
- Resolution $\rightarrow$ Spatial Coverage

Promising:
- Behavior Analysis

Applications:
- Validation of deterrence systems
- Quantification of collision
Acknowledgements

PNNL Sequim Marine Biological Laboratory

NREL Wind Energy Test Facility

Bird observers: Shari Matzner, Corey Duberstein, Valerie Cullinan, and Greg Spencer

Advisory panel for the overall system development

Stereo calibration: Chris Fisher and James Joslin