Ecological Applications of Wireless Sensor Networks

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Boston University Summer 2006 Photonics REU: Final Report
This Presentation

- Project Goals
- Wireless Sensor Networks
- Motes
  - Attenuation
  - Calibration
- Field Tests
- Photosynthesis
- Future Work
Project Goals

- Measure ecological data with wireless sensor networks
  - Software
  - Hardware
  - Data Collection

- Show that wireless sensor networks are better than conventional methods for evaluating photosynthesis
Wireless Sensor Networks

- Use small, self-contained sensors called motes
- Data sent with radio, laser, infrared
- Ad hoc network
  - Each mote becomes aware of nearby motes and form a network
  - Self forming
Hop Scenarios

Single-Hop
data is sent directly from a mote to the base station (limited range)

Multi-Hop
data is passed from a mote to other motes and then to the base station (long range)
Collection and Analysis

- MATLAB applications package
  - Data collectors
  - Calibrator
  - Real-time and post analyzers
  - Engineering unit converters
## Our Motes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mica2</th>
<th>Tmote Sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Intensity</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Temperature</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Humidity</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pressure</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Low Power Mode</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Our Uses:</strong></td>
<td>Large scale light collection</td>
<td>Bat barn animal study</td>
</tr>
</tbody>
</table>
Two 7-bit counts
- If ch0 or ch1 count > 1111111
  - Overflow
  - Sensor saturates
Sensor Attenuation

- Sensor filters
  - 1000x wratten
  - ~5x paper
Calibration

- Heavy attenuation requires calibration

- Difficult to calibrate for large range of light
  - 12 hour test (sunrise to sunset)

- Calibrate each mote against a very accurate control light sensor
  - ADC mote
Calibration Solution

- Voltmeter to measure control sensor
- Log data by hand
- Linear calibration equation for each mote

![Linear calibration equation](image.png)
Open Field Test

- 11 Mica2 motes
  - Record light intensity
  - Multi-hop scheme

- Video
  - Mote layout
  - Animated plots
    - Contour plot
    - Surfaced plot
Video
Static Photosynthesis Models

- Light intensity is only independent variable
- Input parameters dependent upon species

Non-rectangular (Peri et al.):

\[ P(h) = \frac{P_{\text{max}} + \alpha h - \sqrt{(P_{\text{max}} + \alpha h)^2 - 4\theta \alpha P_{\text{max}}}}{2\theta} \]

Rectangular \( \theta = 0 \) (Sullivan et al.):

\[ P(h) = \frac{\alpha h P_{\text{max}}}{\alpha h + P_{\text{max}}} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h )</td>
<td>light</td>
</tr>
<tr>
<td>( P_{\text{max}} )</td>
<td>maximum photosynthetic rate at saturation</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>initial slope of the light-response curve</td>
</tr>
<tr>
<td>( \theta )</td>
<td>curvature indicator</td>
</tr>
</tbody>
</table>
Dynamic Photosynthesis Model

- Dynamic equation varies with time

\[ P(t, h) = P_{t-1} + (P_t - P_{t-1})e^{-t\tau} \]

- Accounts for increases and decreases in light
- Utilizes predicted steady-state values from the previous models
- (Naumburg et al.)
Conventional Photosynthesis Analysis
WSN Photosynthesis Analysis
Future Work

- Bat barn field test
  - Collect environmental data (light, temp, hum.)
- Get better calibrations
- Apply photosynthesis equations to light data
- Simulate conventional methods with WSN light data
  - Evaluate WSN effectiveness
Summary

- Wireless sensor networks collect data easily and efficiently at high resolutions
  - Useful in ecological studies

- Sensors must be adjusted to suit the testing environment
  - Attenuation
  - Calibration

- Field tests don’t always go as planned
  - Murphy’s law

- Photosynthesis equations should be better behaved with WSN data
We would like to thank the NSF, Boston University, and Professor Tom Little for this great research opportunity.

Any Questions?
References


- Peri, P.; Moot, D; and McNeail, D. “A canopy photosynthesis model to predict the dry matter production of cocksfoot pastures under varying temperature, nitrogen, and water regimes.” Grass and Forage Science 58: 416-430.

- Sullivan, N.; Bostad, P; and Vose, J. Estimates of net photosynthetic parameters for twelve tree species in mature forests of the southern Appalachians. Tree Physiology 16: 397-406.