Title

Imagers as Biological Sensors

Authors

Hyman, Josh
Ko, Teresa
Graham, Eric
et al.

Publication Date

2009-05-12

Imagers as Biological Sensors

Josh Hyman, Teresa Ko, Mark Hansen, Eric Graham, Stefano Soatto, Deborah Estrin
Center for Embedded Networked Sensing - http://www.cens.ucla.edu

Introduction: Use imagers to capture hard-to-measure natural phenomena

Some phenomena are difficult to measure

- **Existing sensors are cannot be used in the field**
  Measuring some biological phenomena, like CO_2 uptake, requires ***destructive*** or ***invasive*** instrumentation. Such modification of the environment make any resulting measurement unrepresentative of the phenomena.
- **The phenomena occurs over a large spatial-temporal area**
  Automated approaches towards detecting the presence of species can dramatically improve the scope in which an ecologist can investigate ecological change.

Use imagers to measure phenomena

- **Construct a procedure using imagers as sensors**
  Use state-of-the-art computer vision, image processing, and statistical learning algorithms to model the target signal using ***domain relevant features***. Potentially acquire training data from representative ***laboratory experiments***.
- **Collapse hours of video into summary statistics**
  Use ***intrinsic properties*** of a particular process instantiation to remove redundancy. These properties will take the form of visual cues or other, more easily deployed, traditional sensors.

Problem Description: Varying field conditions and limited ground truth present challenges

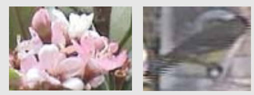
Estimating CO_2 flux

9am 10:30am 12pm

Challenges
- Field lighting conditions are variable
- Not all features are meaningful
- Estimates must be validated

Approach: Extract color based features and infer from a regression based model of CO_2 data collected in a laboratory.

Detecting/cataloging animals



Challenges
- Large background nuisances
- Mimicry
- Low resolution objects of interest
- Unknown categories

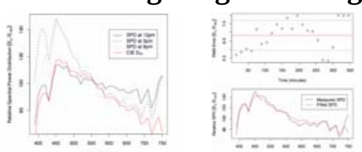
Approach: Enforce spatial-temporal consistency and Categorize "interesting" objects based on multi-view features

Proposed Solution: Construct an application evaluated procedure

Moss CO_2 flux

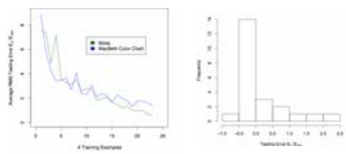
- **Goal:** Ecologists want to determine the effect of short summer rain events on the moss' ability to survive
- **Obstacles:**
  - There are no available sensors
  - Methods suggested by previously ecological studies have insufficient temporal resolution

Incident Lighting Modeling



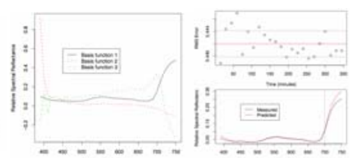
- Measured illumination (left) is similar to D_{65} although it is slightly bluer
- Model (by Judd et. al.) fits well (right top), with a slight temporal component to the error
- Even the sample with largest error has ***minimal error and correct characteristic shape*** (right bottom)

Lighting Estimation



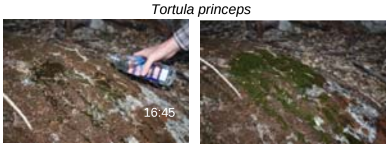
- Uses the Color by Correlation algorithm; accuracy is good with enough training examples (left) With 12 training examples, we find that ***error clusters near zero*** (right)
- Interestingly, performance was comparable with and without JPEG compression

Reflectance Estimation



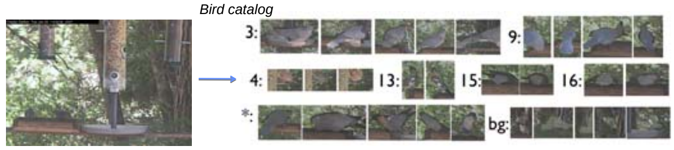
- The variation in the second and third basis functions (left) is expected:
  - variation low and high in the spectra caused by the sensor
  - variation in the middle caused by changes in the moss
- Sample with the maximum error is ***very accurate below 700 nm*** (right bottom)

Tortula princeps



Photosynthesis begins to occur 5 minutes after being hydrated

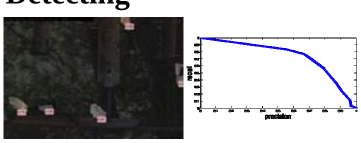
Bird catalog



Bird species catalog

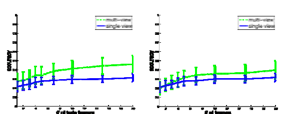
- **Goal:** Ecologists want to know the changes in bird species to a particular ecosystem
- **Obstacles:**
  - There are no available direct sensors
  - Methods suggested by previously ecological studies have insufficient spatial/ temporal resolution

Detecting



- A background model is constructed by incorporating both the spatial and temporal variation.
- Classify a pixel as foreground based on the discrepancy of the color values of its spatial neighborhood relative to the background model.

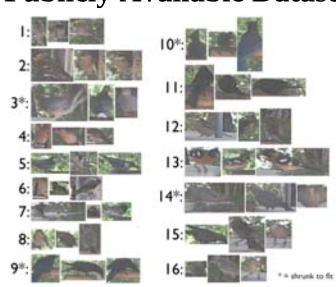
Categorizing



- Group overlapping detections (in time) as a single object and treat each detection as a view.
- Cluster based on the following discrepancy measure:

$$D(\mathbf{H_c}, \mathbf{H_o}) = \max\left(\frac{1}{|H_c|}\sum_{a \in H_c} \max_{b \in H_o} d(a,b), \frac{1}{|H_o|}\sum_{b \in H_o} \max_{a \in H_c} d(a,b)\right).$$

Publicly Available Dataset



http://vision.cs.ucla.edu/~tko