Title
Imagers as Biological Sensors

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

**Some phenomena are difficult to measure**

- **Existing sensors are not be used in the field**
  Measuring some biological phenomena, like CO₂ 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 CO₂ flux**

- **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 CO₂ 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 CO₂ 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 previous ecological studies have insufficient temporal resolution

**Incident Lighting Modeling**

- **Challenges**
  - Measured illumination (left) is similar to D₆₅ 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**

- **Challenges**
  - Use 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**

- **Challenges**
  - 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)

**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:
    \[ D(H, H_b) = \sum_{i=1}^{B} \frac{1}{m(i)} \sum_{n=1}^{N} \left( \frac{H_n(i) - H_b(i)}{m(i)} \right) \]

**Publicly Available Dataset**

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