

TEOS 04 Plant Phenology using Ground-Based Cameras

TEOS 04.1 People

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TEOS 04.2 Overview

The use of imagers as biological sensors has been a main focus of CENS in the last year. One aspect of this is the identification of methods and approaches to identifying plants in natural area images and quantifying aspects such as total leaf area, numbers of flowers, and changes in seasonal vegetation cover. We have been exploring the use of color transformations and probability distributions to segment natural images for quantifying plant phenology.

TEOS 04.3 Approach

Natural scene images have uncontrolled lighting. To avoid some of the more extreme lighting conditions, we have been capturing images from the James Reserve webcams in the early morning and late afternoon. Nevertheless, shadows and changes in the color of the illumination make classification of plant parts difficult in that that the color variation within the image is principally dominated by variations in luminance due to lighting conditions.

To address this problem, a variety of transformations of the RGB color space have been used by other researchers. Linear transformations, relying upon color difference to reduce the effect of luminance, as for the Yxy, HSV, HSL, ATD, and Lab color spaces.. An alternative approach is to normalize the color channels to cancel the effect of illumination intensity, as for the NDI, Normalized RGB, Excess RGB color spaces. This alone, however, does not compensate fully for outdoor lighting variation and so an approach using semi-supervised clustering of chromaticity values to characterize plant and background pixel colors was attempted. As a further test, an ideal color space will have adjacent colors that are more similar to the natural colors found in outdoor scenes, such that smoothing of the color space probabilities will result in better prediction of plant parts from background.

TEOS 04.4 System(s) Description and/or Experiments

We have created three training sets of images: (1) a set of rhododendron leaf images from bud burst to full leaf flush with soil and branches in the background, (2) a set of wallflower images, where wallflowers are yellow against a soil background, are a very small percentage of the images, and counts of flowers is more important than numbers of pixels identified, and (3) a set of Ceanothus flower images that contain blue flowers against a background of green leaves.

We have created a system where these training sets of images are masked for the regions of interest and then pixel counts of values of color components (e.g., only a Red value of 150 in the Red-Green-Blue color space) are created for masked regions and whole images. The counts of pixels in the masks for values of a specific color component are then divided by the counts for the entire image for the same values of color, resulting in a probability that a pixel value in a color component belongs to the foreground or background. These probabilities are then used to predict foreground vs. background in non-training set images (we used >50% probability to classify foreground from background).

The color spaces tested include three-dimensional color volumes, many derived from the Commission Internationale de l'Éclairage (CIE) systems of

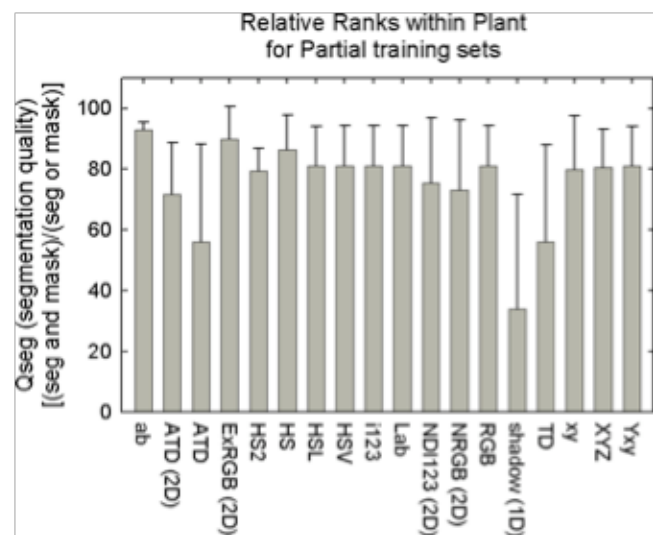


Figure. 1. Relative ranks for color spaces for separating various plant parts from the background in natural images.

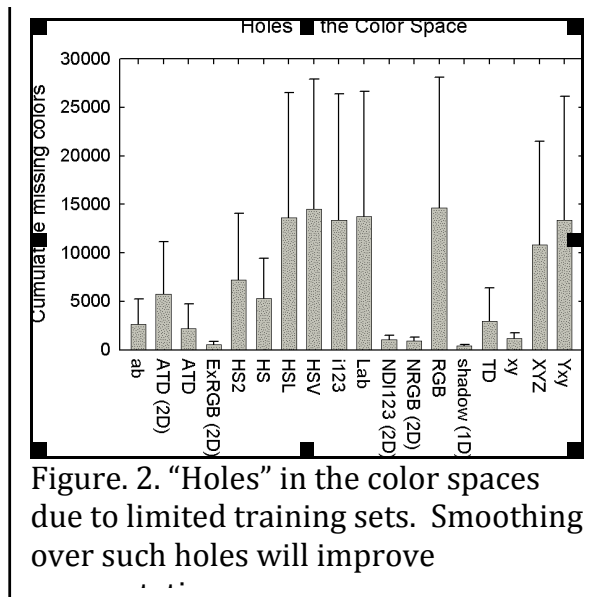


Figure 2. “Holes” in the color spaces due to limited training sets. Smoothing over such holes will improve

modern colorimetry: RGB (native to the camera), Lab (CIE uniform color space), Hue-Saturation-Value (HSV), Hue-Saturation-Luminance (HSL), Achromatic-Tritanoptic-Deuteranoptic (ATD), i123 (Ohta *et al.* 1980), XYZ (CIE tristimulus), Yxy (CIE chromaticity).

Two-dimensional color areas were also tested, many just the chromatic coordinates of the above 3D color volumes: TD (of ATD), xy (of Yxy), HS (of HSV), HS2 (of HSL), ab (of Lab), ExRGB (a 2D plane representation of the 3D Excess Red, Excess Green, and Excess Blue color volume [Excess Red is defined as 2R-G-B, others are similar]), ATD2D (a 2D projection of the ATD color volume), Normalized RGB (a 2D projection of the 3D color volume [Normalized Red is defined as R/(R+G+B), others are similar]), Normalized Difference Index (NDI; Perez *et al.* 2000).

Additionally, a one-dimensional color value was tested, a shadow-invariant transform (Marchant and Onyango

2000).

A segmentation quality index was used to assess the ability of a color space to segment the foreground from the background. Quality ranges from 1.0 for a perfect match between the user-generated mask and the automatic image segmentation to 0.0 for no match:

$$Q_{seg} = \frac{\text{correct segmentation count}}{\text{correct count} + \text{incorrect count}}$$

Where the *incorrect count* is of those pixels identified by the mask but not the segmentation plus those by the segmentation of the image and not by the mask.

TEOS 04.5 Accomplishments

Testing continues, however results with different vegetation indicate that a few color spaces are better at distinguishing plant parts from background, specifically the ab, ExRGB, and HS color spaces (Figure 1). Additionally, due to the limited training sets used for creating pixel probabilities, some color space values are absent, creating “holes” in the predictive matrix (Figure 2). Such holes contribute to the success of a color space for correctly segmenting images.

TEOS 04.6 Future Directions

Work is almost complete. We will add an image sequence for testing the separation of green leaves of oak from that of pine or cedar. We will then re-run the tests with the color spaces “smoothed” to remove the holes in the color spaces to then decide on a best color space to use for our natural images.

After this work is complete, we will then use this method for identifying and quantifying the phenology of various species of plants captured by the James Reserve tower cams and other available cameras.