Leafsnap: A Computer Vision System for Automatic Plant Species Identification

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Abstract. We describe the first mobile app for identifying plant species using automatic visual recognition. The system – called Leafsnap – identifies tree species from photographs of their leaves. Key to this system are computer vision components for discarding non-leaf images, segmenting the leaf from an untextured background, extracting features representing the curvature of the leaf's contour over multiple scales, and identifying the species from a dataset of the 184 trees in the Northeastern United States. Our system obtains state-of-the-art performance on the real-world images from the new Leafsnap Dataset – the largest of its kind. Throughout the paper, we document many of the practical steps needed to produce a computer vision system such as ours, which currently has nearly a million users.

1 Introduction

In this work, we describe a visual recognition system for automatic plant species identification. The system, called Leafsnap, is a mobile app that helps users identify trees from photographs of their leaves (see Fig. 1). The current version of Leafsnap has coverage for all of the 184 tree species of the Northeastern United States. To date, nearly one million copies of Leafsnap have been installed on iPhones and iPads. It is now being used by scientists, ecologists, foresters, urban planners, amateur botanists, gardening clubs, landscape architects, citizen scientists, educators, and even school children in classes across the United States.

Leafsnap was developed to greatly speed up the manual process of plant species identification, collection, and monitoring. Without visual recognition tools such as Leafsnap, a dichotomous key (decision tree) must be manually navigated to search the many branches and seemingly endless nodes of the taxonomic tree. Identifying a single species using this process – by answering dozens of often-ambiguous questions, such as, "are the leaves flat and thin?" – may take several minutes or even hours. This is difficult for experts, and exceedingly so (or even impossible) for amateurs.

In this work, we show how computer vision can be used to significantly simplify the plant species identification problem. Our automatic system requires that a

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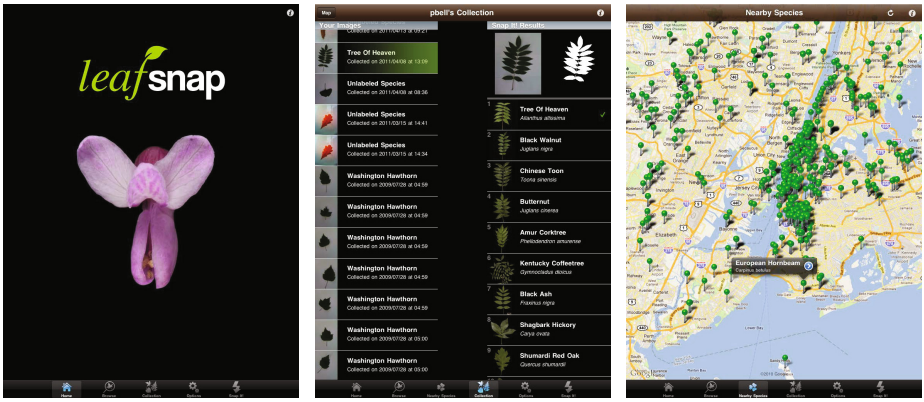

(a) Home (b) Recognition (c) Nearby Species

Fig. 1. Screenshots of the iPad version of Leafsnap. (a) The Home screen, with an image of a flower from the Redbud tree (*Cercis canadensis*). (b) A user's collection (left) and recognition results for a leaf (right), with the image and corresponding segmentation at the top and ranked species results below. (c) The Nearby Species screen, with pins denoting trees recently labeled by Leafsnap users around New York City.

single leaf specimen is photographed on a solid light-colored background. The recognition process consists of:

Classifying whether the image is of a valid leaf, to decide if it is worth processing further, using a binary classifier applied to gist features [1]. (Section 2)

Segmenting the image to obtain a binary image separating the leaf from the background. We do this by estimating foreground and background color distributions in the saturation-value space of the HSV colorspace. (Section 3)

Extracting curvature features from the binarized image for compactly and discriminatively representing the shape of the leaf. We robustly compute histograms of curvature over multiple scales using integral measures of curvature. (Section 4)

Comparing the features to those from a labeled database of leaf images and returning the species with the closest matches. Due to the discriminative power of the features and the size of our labeled dataset, we use a simple nearest neighbor approach with histogram intersection as the distance metric. (Section 5)

All computation is completed in about 5 seconds, and can be trivially parallelized across many machines. Users are then shown the top matches and make the final identification themselves, by examining additional content present in the app, such as high-quality images of the species and textual descriptions of their characteristics. The complete Leafsnap system is discussed in Sec. 6.

Automatic species identification has been an area of recent but growing interest in computer vision. [2] describes a system that combines human input with computer vision results to assist in the identification of birds. In the plant world, [3] describes a system that can automatically identify plant species using images of flowers. While this system shows impressive results, its concerns