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MARCH: Multiscale-arch-height description for mobile retrieval of leaf images

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A B S T R A C T

In this paper, we propose a novel shape description method for mobile retrieval of leaf images. In this method, termed multiscale arch height (MARCH), hierarchical arch height features at different chord spans are extracted from each contour point to provide a compact, multiscale shape descriptor. Both the global and detailed features of the leaf shape can be effectively captured by the proposed algorithm. MARCH descriptors are compared using a simple L_1-norm based dissimilarity measurement providing very fast shape matching. The algorithm has been tested on four publicly available leaf image datasets including the Swedish leaf dataset, the Flavia leaf dataset, the ICL leaf dataset and the scanned subset of the ImageCLEF leaf dataset. The experiments indicate that the proposed method can achieve a higher classification rate and retrieval accuracy than the state-of-the-art benchmarks with a more than 500 times faster retrieval speed. A mobile retrieval system embedding the proposed algorithms has been developed for the real application of leaf image retrieval.

1. Introduction

Rapid and accurate plant identification is essential for effective study and management of biodiversity, as well as contributing to biosecurity measures. The number of plant species is estimated to be around 400,000, however there still exist many species which are yet unclassified or unknown [43]. Therefore, automated systems for plant identification are a very important although challenging task. Leaf shapes vary between different species, thereby providing valuable cues for the identification of the species. Unlike plant flowers which have complex 3D structure and can only be obtained during blooming season, plant leaves are generally thin and flat, and can be found throughout the year. For these reasons, taking pictures of leaves and applying the technologies of pattern recognition and image processing for automatic plant species identification has already attracted considerable attention from researchers [12,27,34,42]. This computer vision based technology greatly accelerates the manual process of plant species identification, collection and monitoring.

Modern smart phones embody incredible convenience and performance in an affordable compact low-powered device. These devices possess onboard cameras, GPS receivers and data communication systems. The ubiquity and functionality of smart phones makes them perfect for field use in a mobile leaf identification system. With such a system, an ordinary user

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can take a picture of a leaf using their phone and obtain detailed information about the plant, including its characteristics, related species, geographic abundance, etc. via the internet. The mobile system allows powerful leaf identification tools to be accessible to anyone, for use at anytime and anywhere. This has benefits for not only ecologists and amateur botanists, but also for educators. In this work, we focus on developing an algorithm for automatic leaf retrieval highly suited for deployment on mobile devices, for aiding the identification of plant species.

The method of effective feature extraction of leaf shapes and measuring their dissimilarity is a key problem in leaf identification and is also a crucial step in a mobile leaf retrieval system. Although many shape description and dissimilarity measurement methods [30,49] have been proposed, with some of them [2,14,20,27,43], being applied to leaf identification in the past two decades, the following problems still make it a challenging task for mobile devices. (1) The leaf shapes usually have a high inter-class similarity and large intra-class difference making it very difficult for the retrieval system to achieve desirable accuracy. (2) Mobile devices have less available RAM, storage and network bandwidth; therefore the extracted shape features should be as compact as possible. (3) Mobile devices have less processing power than most other computers and with the large size of many image databases, the algorithms for extracting and comparing shape features must have a low time complexity. For these reasons, many existing shape description and matching algorithms, though they work very well on powerful computers, are intractable on mobile platforms.

The above challenges motivate us to develop a novel shape description and matching method for fast and effective mobile retrieval of leaf images. The preliminary version of this work was presented in [41]. In this paper, we improve the original algorithm and extend the evaluation of the algorithm against a number of leaf image datasets. The main contributions of this work are as follows. (1) A multiscale-arch-height descriptor, termed MARCH, is proposed in this paper. In this method, the hierarchical arch height features are extracted, providing a coarse-to-fine shape description. The dissimilarity measure for shape matching is the L_1 metric. Compared to the state-of-the-art shape description methods, including the well-known Inner-Distance Shape Context descriptor (IDSC) [29], the proposed MARCH achieves the highest classification rates on the four publicly available leaf image datasets including the well-known Swedish leaf dataset, Flavia leaf dataset, 5720 samples of 220 species of plant leaves from the ICL leaf image dataset and the shape-based-feature methods on the scanned subset of the ImageCLEF leaf dataset. The retrieval experiments on the ICL dataset indicate that the proposed method achieves the highest retrieval accuracy at a speed of over 500 times faster than the state-of-the-art benchmarks. (2) A prototype system for online plant leaf identification was developed for use on a consumer mobile platform. The system embeds the proposed MARCH algorithm and provides high retrieval accuracy and fast retrieval speed (only requiring 0.277 s to retrieve matches from the ICL dataset on an entry-level mobile phone using Java).

The remainder of the paper is organized as follows. A brief review of related work is presented in Section 2. In Section 3, we describe the details of the proposed MARCH multiscale-arch-height descriptor. Section 4 provides the architecture of the proposed mobile retrieval system. In Section 5, a number of experiments are presented and the performance compared and analyzed. The mobile platform implementation of the proposed MARCH algorithms is then presented for real leaf image retrieval applications. Finally, we draw conclusions in Section 6.

2. Related work

The existing methods for shape representation and identification can be classified into contour-based and region-based methods [8,49]. In the former one, the shape features are extracted only from the contour, while in the latter one, the shape features are extracted from the whole shape region. Up to now, many contour-based descriptors and region-based descriptors have been proposed for leaf shape recognition. A recent survey of existing approaches for plant species identification can be found in [9,21]. Among them, Wang et al. [42] use the center distance curve, which is generated by calculating the distance between the center of the contour and each contour point, combined with the shape eccentricity and angle code histogram to represent the leaf shape. Du et al. [14] extract invariant moment features and geometric features including aspect ratio, rectangularity, area ratio of convexity, eccentricity, etc. to describe leaf shape. Wang et al. [43] describe the leaf shape using seven Hu geometric moments and sixteen Zernike moments derived from the binary leaf image. Söderkvist [38] combined moments, area and curvature for leaf classification and reported 82% recognition rate on the Swedish leaf dataset [38]. Im et al. [20] proposed a hierarchical polygon approximation representation of leaf image to recognize species in the Acer family. Lee and Chen [28] extracted the shape region features including aspect ratio, compactness, centroid and horizontal/vertical projections. These methods can provide quite compact shape descriptors, however their limited discrimination ability causes their recognition accuracies to be far from ideal. For example, Lee and Chen [28] reported that their method obtained recall rate of 48.2% for 10 returned images on a small leaf database of 60 species with 10 samples in each. In their reported results, the method of Wang et al. [42] only obtained 37.6% recall rate. The Sabanci Okan methods [46] used a collection of 14 different morphological and texture features to describe the leaf contour and surface, and used nonlinear SVM for classification and attained the highest average classification rate of algorithms included in ImageCLEF 2012 [21].

Apart from extracting the leaf shape features in spatial domain, the leaf shape is also analyzed in the frequency domain. Fourier descriptors [47] are a classical shape description method which have proven to be better than other boundary based techniques [23,48]. McLellan and Endler [32] compared Fourier descriptors with several other methods demonstrating that Fourier descriptors can discriminate successfully between various leaf groups. Hearn [18] applied the Fourier descriptors to the automated identification of plant leaves and suggested that 10 Fourier harmonics are necessary to accurately