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Plant identification using leaf shapes—A pattern counting approach

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ABSTRACT

Plant identification is required by all walks of life, from professionals to the general public. Nevertheless, it is not an easy job but requires specialized knowledge. In this paper, we propose a new method for plant identification using shapes of their leaves. Different from existing studies which target at simple leaves, the proposed method can accurately recognize both simple and compound leaves. In specifics, we propose a novel feature that captures global and local shape information independently so that they can be examined individually during classification. Furthermore, we advocate that when comparing two leaf individuals it is better to "count" the number of certain shape patterns rather than to match the extracted shape features in a point-wise manner. The proposed counting-based shape descriptor is not only discriminative for classification but also computationally fast and storage cheap. Experiments conducted on five leaf image datasets demonstrate that our algorithm significantly outperforms the state-of-the-art methods in terms of recognition accuracy, efficiency and storage requirement.

1. Introduction

Plant identification is not solely the job of botanists and plant ecologists. It is required by all walks of life, from professionals such as landscape architects, arborists, herbal doctors, conservationists, and biologists, to the general public like ecotourists, hikers, park visitors and nature lovers. However, plant identification is not an easy job, but requires specialized knowledge and in-depth training in botany and plant systematics. Nowadays, with the rich development of information technology, it is desired [1,2] to have an automated plant identification system, so that a user can take picture of a plant in the field by a build-in camera of a mobile device and feed it to a pre-installed recognition program to find out the information of the possible species.

Among the organs of a plant, such as flower, fruit, stem and bark, leaf is often used for plant identification since its features are more universal and persistent. Although such characters are applicable in computer systems, accurate recognition of leaves still remains challenging: (1) a leaf can be imaged under arbitrary poses and its parts can articulate. For instance, the relative pose of its petiole and blade can change in different images. (2) Due to morphological variation, the shape of a leaf has large intra-class difference and inter-class similarity. For instance, some plant species have similar overall shapes but different margin details. Ignoring such an important fact, existing approaches have difficulties in achieving good performance. (3) Compound leaves[1] are in particular difficult to recognize, and existing studies [3–5] that are designed for the recognition of simple leaves[2] can hardly be applied directly. It is because the variation of a compound leaf is not only caused by morphological differences of leaflets[3], but also by change in leaflet number and arrangement (Fig. 1).

In this paper, we propose a novel algorithm that can accurately recognize both simple and compound leaves. In specifics, inspired from plant systemtatics, we propose a novel feature that is not only robust to articulation and in-plane rotation, but also able to capture biological information (overall shape, margin type, leaflet geometry and arrangement) better than existing methods. Moreover, we find that these features have patterns which are common to leaves of various species across different datasets. We discover such shape patterns using a learning approach and they, to some extent, act like taxa[4] in plant systematics – each shape pattern describes a common characteristic of many species and all the patterns together form a discriminative principle for recognition. Finally, unlike existing methods that match shape features across leaf individuals, we summarize the number of such patterns used in representation of the entire leaf and take the resultant counts as the descriptor for classification. Experiments conducted on five datasets demonstrate that the proposed method significantly outperforms state-of-the-arts in terms of recognition accuracy, efficiency as well as storage requirement.

The remainder of this paper is organized as follows: Section 2 reviews related works, and Section 3 introduces the most relevant

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[1] A kind of leaf whose blade can be separated into smaller units – called leaflets

[2] A kind of leaf that has a single blade with a bud or a stipule at the base of petiole.

[3] A smaller unit that constitutes a compound leaf.

[4] A unit of classification in biology that is characterized by specific common features.

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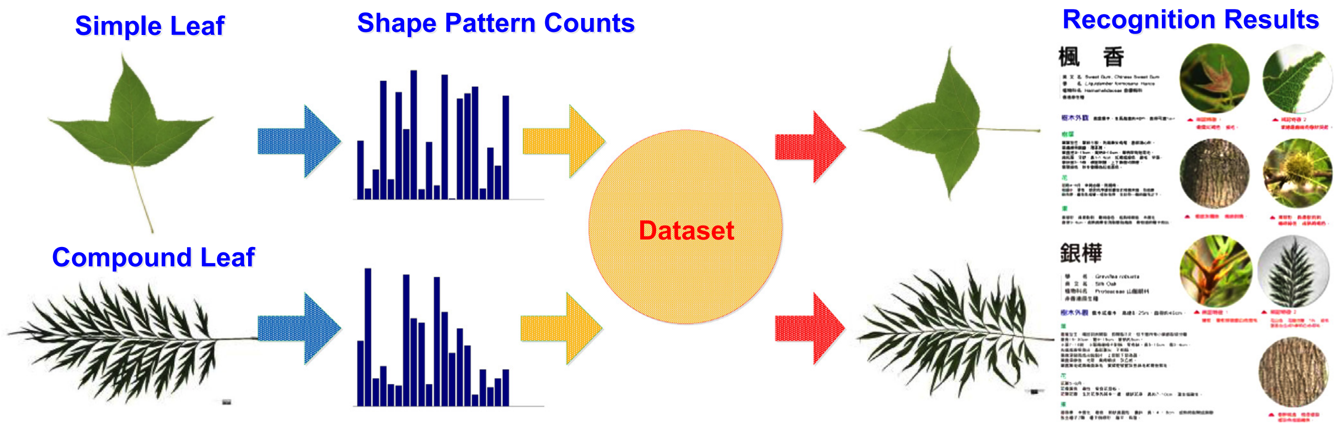

Fig. 1. Description of the proposed plant identification system.

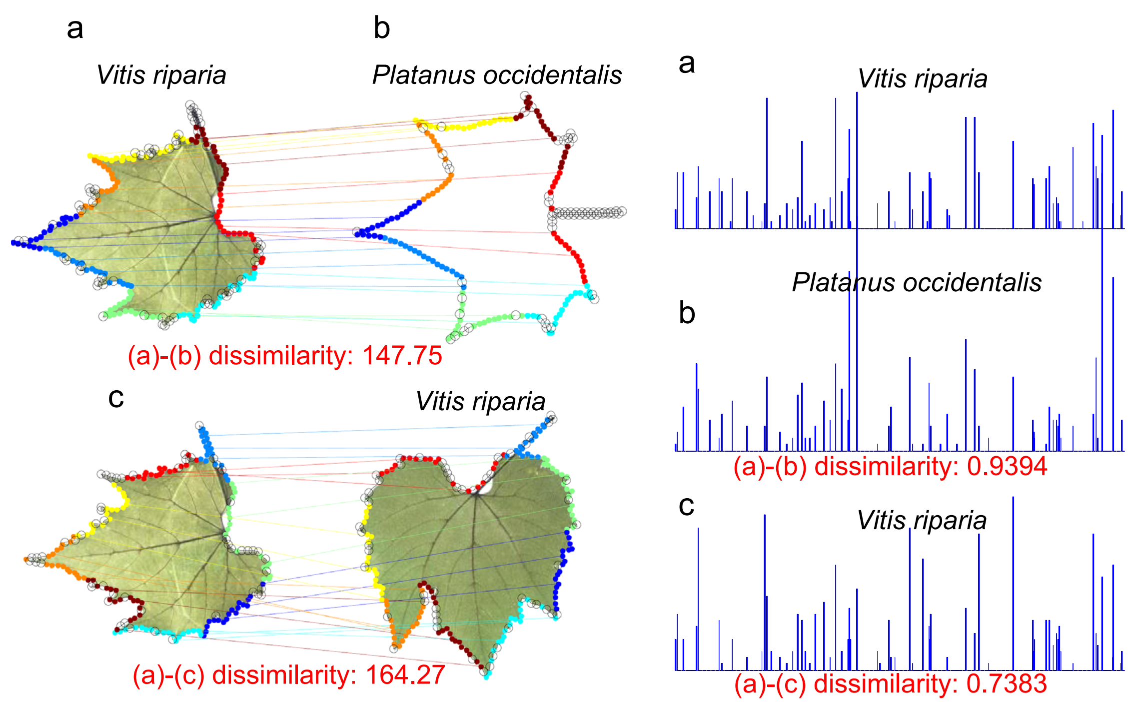

Fig. 2. Dissimilarity scores calculated by feature matching v.s. pattern counting. *Left*: matching IDSC features using dynamic programming [9], where *colored points* indicate matched point in pairs and *black circles* indicate unmatched points; *Right*: counting shape patterns and comparing the histograms in the proposed approach.

method and analyzes its problems under practical scenarios. We describe our proposed method in Section 4, and test its performance in Sections 5 and 6 in comparison with state-of-art approaches. Finally we close this paper by drawing conclusions and discussing future work in Section 7.

2. Related work

Leaf image recognition has recently started attracting research efforts in computer vision and related areas. A major line of such work includes those measuring geometric features. For instance, Wu et al. [4] used aspect ratio, rectangularity and narrow factor as features, and employed Neural Network as the classifier. They achieved up to 90.3% recognition rate on a 10-species dataset. Pahalawatta et al. [5] used a different set of features – stem-to-blade ratio and compactness. A common downfall of these approaches is that the geometric features are difficult to be accurately extracted under imperfect measurements, and weighting between them is also problematic. Therefore, they cannot differentiate a large number of species.

Another line of work makes use of shape descriptors. Soderkvist [3] combined Curvature Scale Space, Fourier descriptor and Hu's moments in building a tree-structured classification system, and tested on the Swedish dataset including 15 species. Ling et al. [9] proposed a novel shape descriptor, called Inner-Distance Shape Context (IDSC) that was reported to perform much better. It measured the similarity between two leaves by establishing a point-point match between their IDSC features. This methodology was further exploited for developing a working system [10], and it was not until that time leaf classification became easy to use in real-life. Though they achieved impressive results on simple leaf recognition, their method did not work well on serrate leaves and compound leaves, as will be explained in Section 3. Very recently, several researchers realized the unsuitability of using shape-matching for leaf image recognition, and proposed to use curvature histograms [11] and linear subspaces [13]. However, these methods either needed special treatment of leaf petiole or could not achieve good results as ours does, as will be explained in Section 5.

Several efforts have also been found using flowers [6] for plant recognition. Their method combined many visual features together, and