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Interactive plant identification based on social image data

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ABSTRACT

Speeding up the collection and integration of raw botanical observation data is a crucial step towards a sustainable development of agriculture and the conservation of biodiversity. Initiated in the context of a citizen sciences project, the main contribution of this paper is an innovative collaborative workflow focused on image-based plant identification as a mean to enlist new contributors and facilitate access to botanical data. Since 2010, hundreds of thousands of geo-tagged and dated plant photographs were collected and revised by hundreds of novice, amateur and expert botanists of a specialized social network. An image-based identification tool – available as both a web and a mobile application – is synchronized with that growing data and allows any user to query or enrich the system with new observations. An important originality is that it works with up to five different *organs* contrarily to previous approaches that mainly relied on the leaf. This allows querying the system at any period of the year and with complementary images composing a plant observation. Extensive experiments of the visual search engine as well as system-oriented and user-oriented evaluations of the application show that it is already very helpful to determine a plant among hundreds or thousands of species. At the time of writing, the whole framework covers about half of the plant species living in France (2200 species), which already makes it the widest existing automated identification tool (with its imperfections).

1. Introduction

Building accurate knowledge of the identity, geographic distribution and uses of plants is essential for a sustainable development of agriculture as well as for biodiversity conservation. Unfortunately, such basic information is often only partially available for professional stakeholders, teachers, scientists and citizens, and often incomplete for ecosystems that possess the highest plant diversity. A noticeable cause and consequence of this sparse knowledge, expressed as the *taxonomic gap*, is that identifying plant species is usually impossible for the general public, and often a difficult task for professionals, such as farmers or foresters and even for the botanists themselves. In this context, image-based identification of plants is considered as one of the promising solution to help in bridging the taxonomic gap (Goëau et al., 2011a, 2011b). With the recent progress in digital cameras, network bandwidth and information storage capacities, the production of multimedia data has indeed become an easy task. In parallel, the explosion of data has fostered the emergence of innovative multimedia analysis and understanding techniques that have demonstrated their effectiveness in many browsing and retrieval applications (Chang et al., 2012).

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Initiated in the context of a citizen sciences project, the main goal of the trans-disciplinary work presented in this paper is to speed up the collection and integration of raw botanical observation data, while providing to potential users an easy and efficient access to a rich botanical knowledge. We therefore did set up an innovative circular and collaborative workflow focused on image-based plants identification as a mean to enlist new contributors and facilitate access to botanical data. Contrary to purely crowdsourced approaches, a key originality of our workflow is to rely on a well established social network specialized in botany[1] to collect, validate or enrich the raw naturalistic observations. Since 2010, hundreds of thousands of geo-tagged and dated plant photographs were collected and revised by novice, amateur and expert botanists of the network. This high-quality collaborative knowledge is already reaching an unprecedented level of diversity in terms of taxa, locations, periods, acquisition devices and illumination conditions (see Section 3.4 for more details).

The image-based identification tool in itself is synchronized with the validated observations so that its recognition performances improve with the increasing amount of training data. It is publicly and freely available as both a web[2] and a mobile application[3], so that anyone interested can use it to identify plants and submit new observations. The increasing success of these applications boosts the amount of new observers and the emergence of a sustainable community of active contributors. As an illustration of the high potential impact of the whole workflow, the mobile application (that was launched in February 2013) was downloaded by more than 40 K iPhone owners in 3 months and the number of sessions is nowadays reaching about 10,000 each week.

Besides this outstanding cross-disciplinary and collaborative realization, another important contribution highlighted in the paper is that the image-based identification tool can work with up to five different "organs" (or more precisely "plant views") contrary to previous content-based methods and systems that relied on a single organ (see Section 2.1 for more details on competitors). It is the first automated visual identification system dealing with multiple image queries and different views of the plant. This allows querying the system at any period of the year contrary to leaf-based or flower-based systems that can be used only when the targeted organ is visible. Furthermore, as shown in the experiments, the performances of the system benefit from the complementarities of the different views to discriminate ambiguous taxa.

A former introduction to this multi-organ approach was presented at the first ACM workshop on Multimedia Analysis for Ecological Data (MAED 2012) and published as a short paper in the proceedings (Goëau et al., 2012a, 2012b). The scope of this new article is much wider and it includes a consistent number of new contributions. First of all, our plant identification system is now working on 2258 plant species (half of the whole French flora) whereas the MAED paper was limited to 127 species of French trees. This makes the system described and experimented in this new paper the widest automated plant identification system built anytime. Other contributions include: (i) an analysis of existing botanical datasets with regard to computer vision and machine learning issues, (ii) the description of the whole Pl@ntNet workflow and not only the visual search engine, (iii) a new fusion algorithm allowing to improve the performances of multi-image and multi-organ queries, (iv) much deeper and larger experiments, and (v) the results of our participation to the plant identification task of ImageCLEF 2011 & 2012 international benchmarks (only reported in unofficial CLEF working notes so far).

The rest of the paper is organized as follows. Section 2 discusses existing works and major challenges in setting up a real-world plant identification system. Section 3 presents the collaborative approach employed and the workflow used to build our image-based plant identification system. Section 4 presents in more details the interactive application and the methods used in our content-based identification system. Section 5 reports evaluation experiments of our system within different contexts (international benchmark, large-scale identification rates & user trials).

2. Towards real-world image-based plant identification tools

2.1. Where we are now

Content-based image retrieval approaches are nowadays considered as one of the most promising solution to help in bridging the taxonomic gap, as discussed in Goëau et al. (2011a, 2011b) or Kumar et al. (2012) for instance. We therefore see an increasing interest in this trans-disciplinary challenge in the multimedia community (e.g. in Cerutti et al., 2011; Goëau et al., 2011a, 2011b; Grozea, 2012; Mouine et al., 2012; Spampinato et al., 2012). Beyond the raw identification performances achievable by state-of-the-art in computer vision algorithms, recent visual search paradigms actually offer much more efficient and interactive ways of browsing large floras than standard field guides or online web catalogs. Smartphone applications relying on such image-based identification services are particularly promising for setting up massive ecological monitoring systems, involving thousands of contributors at a very cheap cost. A noticeable progress in this way has been achieved by the US consortium at the origin of LeafSnap[4]. This popular iPhone application now allows a fair identification of 184 common American plant species by simply shooting a cut leaf on a uniform background (see Belhumeur et al., 2008; Kumar et al., 2012 for more details). Another noticeable initiative is the plant identification evaluation task organized since 2011 in the context of the worldwide evaluation forum ImageCLEF[5]. In 2011 and 2012, respectively 8 and 11 international research groups did participate in this large collaborative evaluation by benchmarking their image-based plant identification systems (see Goëau et al., 2011a, 2011b, 2012a, 2012b for more details). Contrary to previous evaluations reported in the literature, the key objective was to build a realistic and close to real-world conditions task (different users, areas, periods of the year, etc.). The 2012 campaign showed that state-of-the-art techniques allow a correct species identification for about 50% of the submitted query images with respect to a reference catalog of 126 species. On the one side, it reveals the difficulty of building fully automatic identification systems with state-of-the-art computer vision and machine learning technologies. But on the other side, it shows that such technologies can be used as powerful filtering tools and might therefore already lead to successful interactive applications.

It is noticeable that most image-based identification methods and evaluation data proposed in the past were so far based on leaf images (e.g. in Belhumeur et al., 2008; Backes et al., 2009b or in the more recent methods evaluated in Goëau et al., 2012a, 2012b). Only few of them were focused on flower's images as in Nilsback and Zisserman (2008). Leaves are far from being the only discriminant visual key between species but, due to their shape and size, they have the advantage to be easily observed, captured and described. One of the claims of this paper is that more diverse parts of the plants should still be considered complementary to leaves for more accurate identification. As an example, the 6 species depicted in Fig. 1 share the same French common name of "*laurier*" even though they belong to different taxonomic groups (4 families, 6 genera). The main reason is that these shrubs, often used in hedges, share leaves with more or less the same-sized elliptic shape. Identifying a *laurel* can be very difficult for a novice by just observing leaves, while it is undisputably easier with flowers. Beyond identification performances, the use of leaves alone has also some practical and botanical limitations. Leaves are not visible all over the year for a large fraction of

[1] http://www.tela-botanica.org/.
[2] http://identify.plantnet-project.org/fr/base/tree.
[3] https://itunes.apple.com/en/app/plantnet/id600547573.
[4] http://leafsnap.com/.
[5] http://www.imageclef.org/.