Ecological Informatics 23 (2014) 126–136

Contents lists available at ScienceDirect

Ecological Informatics

journal homepage: www.elsevier.com/locate/ecolinf

Automatic habitat classification using image analysis and random forest

Mercedes Torres [a,*], Guoping Qiu [b,c]

[a] University of Nottingham, Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, UK
[b] The University of Nottingham, UK
[c] The University of Nottingham, Ningbo, China

ARTICLE INFO

Article history:
Received 1 February 2013
Received in revised form 1 May 2013
Accepted 19 August 2013
Available online 2 September 2013

Keywords:
Image analysis
Image annotation
Habitat classification
Random forests
Feature extraction

ABSTRACT

Habitat classification is important for monitoring the environment and biodiversity. Currently, this is done manually by human surveyors, a laborious, expensive and subjective process. We have developed a new computer habitat classification method based on automatically tagging geo-referenced ground photographs. In this paper, we present a geo-referenced habitat image database containing over 1000 high-resolution ground photographs that have been manually annotated by experts based on a hierarchical habitat classification scheme widely used by ecologists. This is the first publicly available image database specifically designed for the development of multimedia analysis techniques for ecological (habitat classification) applications. We formulate photograph-based habitat classification as an automatic image tagging problem and we have developed a novel random forest based method for annotating an image with the habitat categories it contains. We have also developed an efficient and fast random-projection based technique for constructing the random forest. We present experimental results to show that ground-taken photographs are a potential source of information that can be exploited in automatic habitat classification and that our approach is able to classify with a reasonable degree of confidence four of the main habitat classes: Woodland and Scrub, Grassland and Marsh, Heathland and Miscellaneous.

1. Introduction

The worldwide fragmentation and destruction of habitats and their economic, biological and ethical consequences are considered to be one of the biggest challenges currently affecting our society (van Kooten et al., 2000). Habitats are defined in the European Union Habitats Directive as "terrestrial or aquatic areas distinguished by geographic abiotic and biotic features, whether natural or semi-natural" (Council Directive 1992/43/EEC). Their classification and characterization have been carried out for more than one hundred years (Andreson et al., 1976) and environmental agencies of countries such as the United Kingdom, Germany, Switzerland, Denmark and the Netherlands (Olsen, 2004) maintain projects related to habitat monitoring.

The purpose of classifying habitats is twofold: first, it helps to reduce the complexity present in the natural world. Secondly, by categorizing habitats, their characterization and comparison can be done much more efficiently and effectively. While there are multiple schemes that have been developed to date, one of the most widely used by ecologists is the Phase 1 Habitat Survey scheme (JNCC, 2010). This standardized hierarchical classification divides all habitats into ten broad categories and it was designed to provide a record of the vegetation and wildlife present in a determined area.

There are many applications to habitat classification, such as habitat monitoring and identification, monitoring and conservation of rare species (Lauver and Whistler, 1993; Martínez et al., 2010; Scemske et al., 1994). However, one of the main drawbacks of Phase 1 Habitat Classification is that it relies very heavily on human surveyors (JNCC, 2010). This is laborious, expensive, time consuming and, given the similarities between some of the habitat classes, subjective. While approaches have been developed with the aim of automating the habitat classification process, to our knowledge, no clear and accurate alternative has been presented to this date. One of the main reasons why fully accurate results have not been obtained is because most of the methods developed use aerial photography or satellite imagery. Given the grade of detail that is necessary to distinguish between some of the habitats collected in the Phase 1 Habitat Survey scheme, both aerial and satellite imagery have been proven to be insufficient.

This paper expands the work previously done in Torres and Qiu (2012) and presents an automatic habitat classification approach that uses ground-taken photographs. Fig. 1 shows a random sample of the type of ground-taken photographs that have been labeled and used to classify habitats. These photographs present two main advantages over aerial and satellite imagery. Firstly, ground-taken photography has a greater degree of detail that could be decisive when differentiating between similar habitat classes. Secondly, they can be obtained more easily than aerial and satellite imagery, since the only equipment necessary is a digital camera.

This paper makes two contributions. First, we present an updated database of over 1000 ground-taken images which have been classified

* Corresponding author: Tel.: +44 7425423375.
E-mail addresses: psxmt3@nottingham.ac.uk (M. Torres), guoping.qiu@nottingham.ac.uk (G. Qiu).

1574-9541/$ – see front matter.
http://dx.doi.org/10.1016/j.ecoinf.2013.08.002

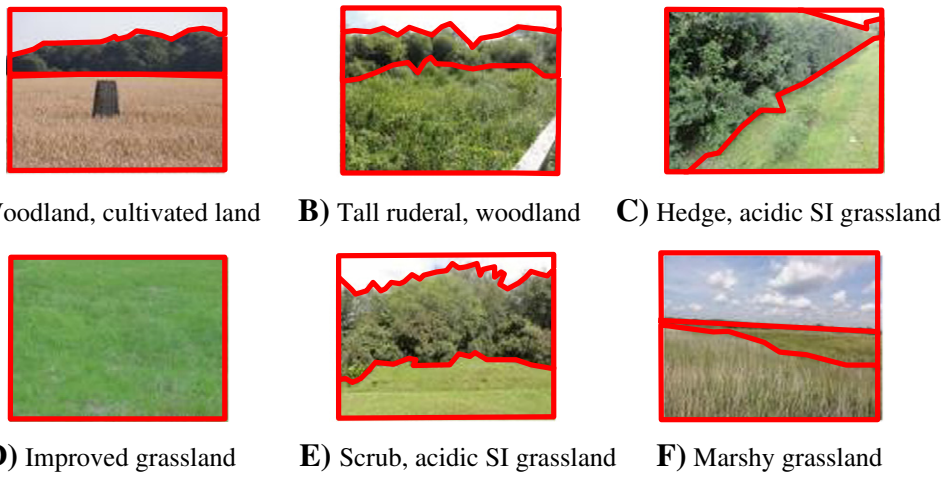

Fig. 1. Examples of (labeled) ground-taken habitat photographs. SI stands for semi-improved.

Table 1
Comparison of manual Phase 1 habitat survey and habitat survey using aerial photography and satellite imagery.

	Phase 1 survey	Aerial photography	Satellite imagery
Data coverage	Complete ground cover possible.	Incomplete for some dates. Variable quality.	Complete cover but data can be obscured by clouds.
Data collection	Direct recording in the field by humans	Relies on tone and pattern of spectral reflectance	More limited range of tones but greater contrast than aerial photography.
Accuracy and interpretation	Accuracy depends on field surveyors. Interpretation problems.	Images are accurate but interpretation can be difficult.	Images are accurate but interpretation can be difficult.
Habitat coverage	Yields complete set of Phase 1 habitat categories	Yields limited set of habitat categories	Yields limited set of habitat categories.
Species information	Gives information on dominant and other plant species.	Little species information	Very little species information.

and tagged by an expert following the Phase 1 scheme. This is, to our knowledge, the first database with such characteristics made publicly available. Second, we use this database to test a novel random forest method (Branson et al., 2011) for automatic habitat classification. We have developed an automatic image tagging style method (Fu et al., 2012; Zhou et al., 2011) to annotate an image with the habitat categories it contains.

2. Previous work

2.1. Habitat classification

Up to this date, there are numerous terrestrial and freshwater habitat classification schemes that have been developed worldwide (Cowardin et al., 1979; Lucas et al., 2011). Examples of these are: Phase 1 Habitat Classification (JNCC, 2010), UK Biodiversity Action Plan for broad habitat types (UK Biodiversity Steering Group, 1995), European Nature Information System (EUNIS) and Coordination of Information on the Environment (CORINE) (Moss and Wyatt, 1994). Although their objectives and parameters are quite different, the classifications results rely heavily on surveyors and manual classification. However, habitat surveying is labor intensive, costly, subjective and can take a significant amount of time (JNCC, 2010). On the other hand, most of the automatic approaches proposed use either satellite imagery (Chen and Rau, 1997; Gislason et al., 2006; Lauver and Whistler, 1993) or aerial images (Cowardin et al., 1979; Thompson, 1996) in their design.

In terms of Phase 1 classification, the use of aerial and satellite imagery to categorize habitats presents several disadvantages, shown in Table 1 (JNCC, 2010).

Moreover, satellite and aerial photographs are difficult to obtain in comparison to ground-taken photographs. However, to the best of our knowledge, the use of ground-taken photographs to classify habitats using a Phase 1 classification has not been attempted before. Therefore, there are no previous results about how accurate ground-taken imagery is when automatically classifying habitats using the Phase 1 scheme.

2.2. Image annotation

From an image processing perspective, automatic Phase 1 habitat classification using ground-taken imagery can be approached as an image annotation problem. In this case, the aim is to identify which habitats are present in which photos and where they are localized. There are many approaches that have been developed for image annotation with general classes. For example, Rabinovich et al. (2007) combined image annotation with semantic information and bag-of-features to classify photographs according to twenty-one classes such as *building*, *grass*, *tree*, *cow*, *water*, *chair*, *road* and *cat*. Shotton et al. (2008) used semantic texton forests to annotate and classify images with a similar classification scheme. Branson et al. (2011) combined interactive and online learning to create a framework that was able to annotate bird images. Lazebnik et al. (2006) also developed a method for indoor and outdoor scene recognition based on partitioning an image into increasingly finer sub-regions and computing their histograms. However, what

Table 2
Habitat classes in the Phase 1 scheme.

	Habitat categories — first tier
A	Woodland and scrub
B	Grassland and marsh
C	Tall herb and fern
D	Heathland
E	Mires
F	Swamp, marginal and inundation
G	Open water
H	Coastland
I	Rock exposure and waste
J	Miscellaneous