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Object-based target search using remotely sensed data: A case study in detecting invasive exotic Australian Pine in south Florida

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Abstract

This study developed an object-based geographic image retrieval (GIR) approach for detecting invasive exotic Australian Pine in south Florida, USA. To filter out non-tree image objects, a hierarchical multi-resolution segmentation and filtering approach was first adopted to segment remote sensing images (DOQQs) into image objects (image regions) of irregular shape, compared to a regular square shape used in the literature. The study then computed object-level spectral, texture, and three-dimensional information for image object content representation using NDVI-based spectral, wavelet transform-based texture, variogram -based texture, and canopy surface height information. The effectiveness of content representation was evaluated using these different properties and their combinations in 10 sets of replica retrieval experiments with 5% random sample fractions of ground-truth identified Australian Pine image objects as query templates. The set of features providing the best fit was found to be a combination of canopy surface height and wavelet transform-based texture. These variables were selected for further tests to determine the similarity threshold beyond which retrieval is regarded as irrelevant. A series of regression tree models were built based on replica retrieval experiments with sample fractions of 1%, 5%, 10%, 15%, and 20%. The predicted results were analyzed to examine the sensitivity of retrieval performance (precision and recall) to the sample fraction and similarity threshold. A moderate retrieval performance was achieved in detecting Australian Pine in the study area. The study suggested that GIR with target search as its major objective by design could be an important supplement to image classification for invasive exotic plant species detection from remotely sensed images.
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Keywords: Geographic image retrieval; Object based; Regression tree; Similarity threshold; Invasive exotic species

1. Introduction

Image classification is a well established approach for deriving thematic information from remote sensing images. The recently developed content-based image retrieval (CBIR) (Flickner et al., 1995; Pentland et al., 1996; Smith and Chang, 1996), or more specifically geographic image retrieval (GIR) in a remote sensing context, represents an essential complement to classification in cases of target search. Searching for specific targets from remote sensing images has a close relationship to, or can be regarded as a particular type of, geographic information retrieval (Purves and Jones, 2006). As a well-established field, information retrieval focuses on a content-based search from unstructured collections of documents with the

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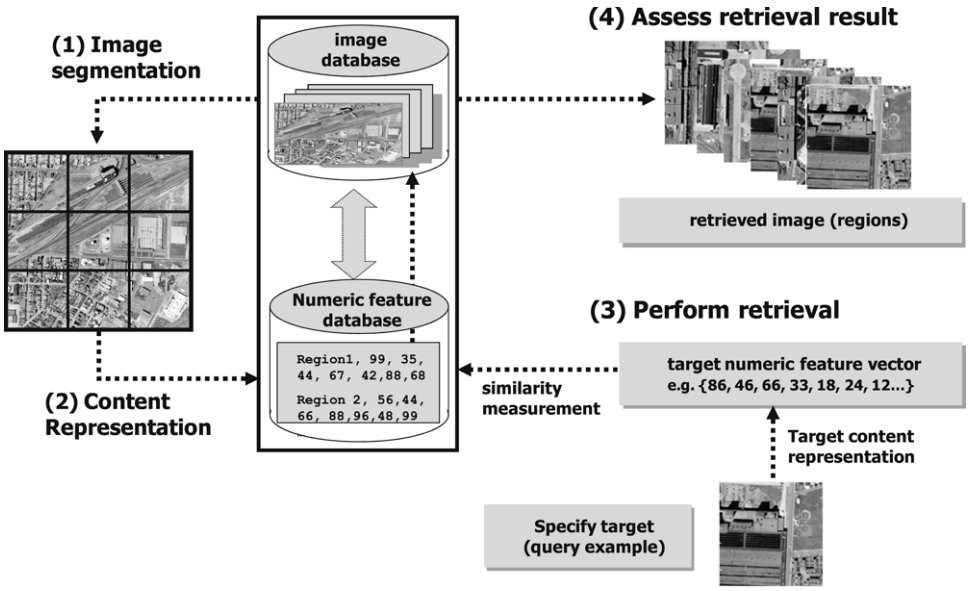

Fig. 1. The general process of GIR (Adapted after Xie (2004)).

retrieved documents being ranked in probabilistic relevance (Van Rijsberger, 1979). A familiar example is a document search on the World Wide Web (Purves and Jones, 2006) using various search engines such as Google, Yahoo, etc. GIR seeks to efficiently retrieve those image regions in a remote sensing image (database) that have a similar geographic content as the target object. The most efficient target search using GIR is when the sole or major objective is to extract (sometimes repetitively) a specific type of object that occupies only a small, but widely scattered, proportion of a relatively large spatial region. Economically feasible data available to support such a task commonly includes remote sensing images, which are often inexpensive or free, but their quality may be less than what is desired. For such tasks, an exhaustive classification of the images is unnecessary and inefficient, and it may not even be feasible due to the cost of acquiring sufficient training samples for various types of terrain features and the time needed to process the usually voluminous data, especially when high resolution images are used. Conversely, GIR could possibly be a good alternative with its limited and focused goal of target search by design.

The general GIR process is illustrated in Fig. 1. Three components are especially important: image segmentation, content representation, and similarity measurement (Xie, 2004). An image is first segmented into individual regions (image objects), which hopefully contain homogeneous semantic content. To represent the content of an image object, a numeric feature vector will be designed and derived out of the remotely sensed data with each element being a measurement of a property of the image object. Then, similarity between query templates (targets) and image objects is assessed using a similarity measurement between their respective numeric feature vectors. The image objects that are the most similar or meet the specified similarity threshold will be retrieved and evaluated.

GIR has been successfully used in detecting generic land use and land cover (LULC) types, as well as urban and industrial targets from remote sensing images (Manjunath and Ma, 1996; Sheikholeslami et al., 1999; Bian, 2003; Bian and Xie, 2004). However, we identified three key aspects that warrant further investigation and improvement. First, a regular square shape image object (image region) was often used as the basic operational unit for image processing, content representation and retrieval in GIR literature (Manjunath and Ma, 1996; Sheikholeslami et al., 1999; Bian, 2003; Bian and Xie, 2004). While a regular shaped image object is appropriate for search tasks where the exact geometric shape is not of significance and the near neighborhood context may be actually beneficial for the content representation in certain circumstances (Bian, 2003; Xie, 2004). An irregularly shaped and semantically pure image object is preferable in other cases such as species level invasive plant detection with high resolution images. It can also be argued that the use of regularly shaped image objects was conveniently adopted largely due to the bottleneck of automatically delineating the