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A relevance feedback method based on genetic programming for classification of remote sensing images

J.A. dos Santos [a], C.D. Ferreira [a], R. da S. Torres [a,*], M.A. Gonçalves [b], R.A.C. Lamparelli [c]

[a] Institute of Computing, University of Campinas, Campinas, SP, Brazil
[b] Department of Computer Science, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil
[c] Center for Research in Agriculture, University of Campinas, Campinas, SP, Brazil

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ABSTRACT

This paper presents an interactive technique for remote sensing image classification. In our proposal, users are able to interact with the classification system, indicating regions of interest (and those which are not). This feedback information is employed by a genetic programming approach to learning user preferences and combining image region descriptors that encode spectral and texture properties. Experiments demonstrate that the proposed method is effective for image classification tasks and outperforms the traditional MaxVer method.

1. Introduction

Brazilian agriculture has obtained efficient, competitive, and dynamic results. In the last decade, agriculture has increased its contribution to the Brazilian Gross Domestic Product (GDP), representing around 10% of the total GDP. Prediction estimates are the basis for policies of the Brazilian government to finance agricultural activities. In this scenario, there is an increasing demand for information systems to support monitoring and planning of agriculture activities in Brazil. Remote sensing images (RSIs) are extensively used for agricultural planning and crop monitoring, providing a basis for decision-making.

RSIs provide the basis for the creation of information systems that support the decision-making process based on soil occupation changes. In these systems, two important issues need to be addressed: how to identify (recognize) regions of interest and, later, how to extract/define polygons around these regions. The use of polygons (vector data) facilitates the creation of thematic maps and their storage into existing commercial storage facilities.

Tasks such as identification and polygon extraction usually rely on classification strategies that exploit visual aspects related to spectral and texture patterns identified in RSI regions. These tasks can be performed automatically or manually.

The "manual" approach is based on image editors used to define or draw polygons that represent regions of interest using the raster image as background. The extraction of polygons from raster images is called *vectorization*.

In general, automatic approaches use classification strategies based on pixel information [26]. The main drawback of these approaches is concerned with their sensitivity to noise in the images (for example, distortions found in mountainous

* Corresponding author. Address: Av. Albert Einstein, 1251, CEP 13084-851 Campinas, SP, Brazil. Tel.: +55 19 3521 5887; fax: +55 19 3521 5847.
E-mail addresses: jsantos@ic.unicamp.br (J.A. dos Santos), crferreira@lis.ic.unicamp.br (C.D. Ferreira), rtorres@ic.unicamp.br (R. da S. Torres), mgoncalv@dcc.ufmg.br (M.A. Gonçalves), rubens@cpa.unicamp.br (R.A.C. Lamparelli).

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regions). Another important problem in the automatic approaches is their known difficulty in correctly identifying borders between distinct regions within the same image. Thus, in practice, the obtained results need to be manually revised. As these revisions may take a lot of time, it is sometimes more convenient to the user to perform recognition manually.

This paper addresses these shortcomings by presenting a semi-automatic approach for RSI classification. The proposed solution relies on the use of an interactive strategy, called *relevance feedback (RF)* [41], based on the idea that a classification system can learn which regions are of interest, with some help of the user. The proposed image classification process with relevance feedback is comprised of four steps: (i) showing a small number of retrieved image regions to the user; (ii) user indication of relevant and non-relevant regions; (iii) learning the user needs from her/his feedback; (iv) and selecting a new set of regions to be shown. This procedure is repeated until a satisfactory result is reached. Our approach only requires the user to identify relevant (or irrelevant) regions, being potentially very easy to use.

In this paper, recently proposed relevance feedback methods for interactive image search [13,25] are extended and adapted for image classification, more specifically for RSI classification. The challenges faced here encompass the fact that RSIs are much more difficult to describe, requiring more effective approaches for combining descriptors.

The used RF method adopts a genetic programming approach to learn user preferences in a query session. Genetic programming (GP) [18] is a machine learning technique used in many applications, such as data mining/classification, signal processing, and regression [3,11,39,35,2]. This technique is based on the evolution theory and aims at finding near optimal solutions. The use of GP in this work is motivated by the previous success of using this technique in information retrieval [11] and Content-Based Image Retrieval (CBIR) [8] tasks.

In [13], a RF approach which exploits the indication of relevant (positive) images is introduced. This method was extended in [25] to deal with image region features. The main objective was to use GP to find a function that combines region similarity values (instead of global features, as presented in [13]) computed by different descriptors, and then learn the user needs. In this paper, we extend both approaches for a new application: classification of remote sensing images. Furthermore, we discuss how to incorporate the user indication of non-relevant regions in the relevance feedback process, an issue not explored in both previous works. These extensions are original contributions of this work.

This article is organized as follows. Section 2 covers related work. Section 3 presents the background concepts necessary to understand our proposed approach. Section 4 introduces our region-based similarity model using GP, including the extensions required to incorporate negative feedback. Section 5 discusses how the proposed model is applied to the problem of RSI vectorization. Section 6 describes our experimental evaluation and is followed by Section 7 that concludes the paper.

2. Related work

This section presents related work associated with classification of RSIs (Section 2.1) and the use of relevance feedback in content-based image retrieval systems (Section 2.2).

2.1. Classification of RSIs

Images provided by satellite sensors have been used in large scale for crop monitoring and production predictions. However, there is not a satisfactory fully automatic method to classify RSIs so far. Terrain distortions and the interference of clouds, for example, make classification a hard problem in this domain. Another important issue is how to provide effective classification strategies considering the different evolution stages of a crop. Traditional classification methods are based on pixel analysis. The most used pixel classification algorithm, MaxVer [26], however, is not very effective. Several new methods have been proposed to improve the performance of MaxVer-based techniques. In [22], a new method considering image segmentation, GIS, and data mining algorithms was presented. Compared with pixel-based classification, their results showed best agreement with visual interpretation. The work proposed in [36] applied a morphological filter in an image which was then classified by the MaxVer algorithm. The results were compared with other classification algorithms (Fisher linear likelihood, minimum Euclidean distance and ECHO). In [16], three Land Cover Classification Algorithms were compared for monitoring North Korea using multi-temporal data.

2.2. CBIR and relevance feedback

CBIR systems provide efficient and effective means to retrieve images. In these systems, the searching process consists of, for a given image, computing the most similar images stored in the database. The searching process relies on the use of image *descriptors*. A descriptor can be characterized by two functions: *feature vector extraction* and *similarity computation*. Feature vectors encode image properties, such as color, texture, and shape. Therefore, the similarity between two images is computed as a function of their feature vector distance.

In some CBIR approaches, the descriptors are statically combined, that is, the descriptor composition is fixed and used in all retrieval sessions. Nevertheless, different people can have distinct visual perceptions of a same image. Motivated by this limitation, *relevance feedback* approaches were incorporated into CBIR systems [24,6,14]. This technique makes possible the user interaction with the retrieval systems.