



Remote sensing image analysis by aggregation of segmentation-classification collaborative agents

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Highlights

- Two new approaches for collaborative remote sensing image analysis are presented. They both are based on a multi-paradigm framework which uses classification to guide a segmentation process.
- The proposed methods aggregate many mono-class extractors in order to make multi-class remote sensing image classification.
- Experiments show that the proposed methods give better results (both in terms of classification and segmentation) than a hybrid object-based approach as well as a deep learning approach, even if the training data is limited in quantity and quality.

Abstract

In this article we present two different approaches for automatic remote sensing image interpretation which are based on a multi-paradigm collaborative framework which uses

classification in order to guide the segmentation process. The first approach applies sequentially many one-vs-all class extractors in a manner inspired by cascading techniques in machine learning. The second approach applies many collaborating one-vs-all class extractors in parallel. We show that the collaboration of the segmentation and classification paradigms result in a remarkable reduction of segmentation errors but also in better object classification in comparison to a hybrid pixel-object approach as well as a deep learning approach.

Introduction

Automatic interpretation of remote sensing images is a very challenging problem and it is rapidly becoming an indispensable requisite for many applications such as disaster management [1], [2], forest mapping [3], urban planning [4], [5], among others. Indeed, images of increasingly high spatial resolution are getting acquired more frequently in such a way that their treatment without any kind of computer assistance becomes intractable.

Object Based Image Analysis (OBIA) [6] techniques are generally used for dealing with Very High Spatial Resolution (VHSR) images. Indeed the object based representation allows for a better description of the image, so knowledge can be more easily extracted. From a ready-for-analysis image, OBIA methods generally use classical segmentation approaches to partition the image into homogeneous regions, hoping for a one-to-one mapping between those regions and geographic objects in the image. Many features are then computed to describe these segments. As a final step, classification approaches are employed to get an entirely labelled image which can be analysed by an expert.

One of the main drawbacks of OBIA is that the classification results are heavily dependant on the segmentation results [7], so classifiers often require ideal segments which perfectly match geographic objects in the image in order to give accurate predictions in the classification step. However, such perfect segments are rarely obtained regardless of the segmentation approach used. Indeed, it is commonly known that due to the variability and complexity of remote sensing images, it is extremely difficult –if not impossible– to find an algorithm (with its corresponding parameters) which produces a full mapping between the segments and the geographic objects in the image. Thus, classical segmentation approaches are not really suitable for OBIA since they tend to output a non-negligible number of over- and/or under-segmented regions and are strongly dependent on their parameters. Moreover, many objects commonly found in VHSR images are composed of several non-homogeneous regions; the roof of a house for example, is often composed of dark and light regions which not likely to be segmented together by a classical segmentation algorithm. Unfortunately, manual correction of such problematic segments is a tedious and time consuming task for the expert. Our idea to automatize this operation is to employ information implicitly encoded into one or more classification models trained offline, in

order to guide a segmentation improving process. Our main hypothesis relies on the fact that when the classification of a given segment is confident, then this segment is likely to correspond to an actual geographic object of interest. Reciprocally, the more a given segment corresponds to a geographic object the higher its classification probability should be, provided that the classification model correctly encodes the semantic information related to the class of interest. In this article, we propose to aggregate many segmentation-classification collaborating agents, each one looking for a single class. More precisely, we propose a sequential approach inspired from machine learning techniques such as cascading [8] and boosting [9]; and a parallel approach inspired from collaborative clustering techniques such as SAMARAH [10].

The following sections are organized as follows. Section 2 presents some work related to our research. Section 3 presents the collaborative framework CoSC on which our proposition is based. Section 4 introduces a sequential scheme of segmentation and classification, and a parallel collaborative approach. Section 5 studies some properties of the proposed methods and presents a comparative study with a hybrid OBIA method as well as a deep learning method and discusses our results. Finally, Section 6 concludes and gives some research perspectives.

Section snippets

Related work

Several attempts to combine segmentation and classification methods have been proposed in order to improve the segmentation and classification processes. We can distinguish two main kinds of such methods. ...

Collaborative segmentation and classification: CoSC

Our proposition is built upon the CoSC framework presented in [18], [19] which we briefly describe in order to make this article self-containing. CoSC is designed to extract a single thematic class from an image. Fig. 1 represents the mono-class CoSC process. It takes three input parameters: an image, an initial segmentation \mathcal{S} and a one-vs-all classifier $\mathcal{C}_{\mathcal{C}}$ trained to label segments corresponding to class \mathcal{C} objects. $\mathcal{C}_{\mathcal{C}}$ gives the probability $P_{\mathcal{C}}(R)$ that a segment $R \in \mathcal{S}$ belongs to class \mathcal{C} ; a reject ...

A sequential aggregation approach: CoSCade

Provided that the searched classes are disjoint, one evident extension of CoSC to deal with multiple classes should be to run many CoSC processes independently, each one on a

specific class, then merge the resulting probability images and segmentations. Nevertheless, this solution does not seem optimal, since each CoSC process would correct the same segmentation errors many times and possibly in a contradictory manner. As introduced in the previous section, experiments show that CoSC gives good ...

Experimental study

In order to validate the proposed approaches, we apply them to extract four classes from a very high spatial resolution image. The classes of interest are: roads (R), buildings (B), vegetation (V) and water (W). In the following subsections we present the studied image and the experimental methodology. We study independently each of the proposed approaches, and we compare them with two other methods from the literature for multi-class remote sensing analysis. ...

Conclusion

In this article we presented two different extensions of the collaborative framework CoSC. The first one, called CoSCade, is a sequential cascading scheme of collaborative segmentation and classification agents to deal with automatic multi-class remote sensing image interpretation. It allows incremental image labelling by extracting one class at a time. The second one, called CoCoSC, follows a parallel scheme alternating a mono-class extraction step with a conflict solving step. Our experiments ...

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...Therefore, the segmentation performance has a critical effect on the later steps of GEOBIA, including object feature extraction and classification (Gonçalves et al., 2019). There are a number of HR image segmentation algorithms proposed and utilized in GEOBIA (Liu et al., 2015; Grinias et al., 2016; Troya-Galvis et al., 2018; Comaniciu and Meer, 2002). For example, watershed segmentation (Li et al., 2010), hybrid segmentation (Wang et al., 2018) and multi-resolution segmentation (Benz et al., 2004) have been widely used to generate image objects in GEOBIA....

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