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Segmentation and thematic classification of color orthophotos over non-compressed and JPEG 2000 compressed images

A. Zabala*, C. Cea, X. Pons

Department of Geography, Universitat Autònoma de Barcelona, 08193 Cerdanyola del Vallès, Spain

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ABSTRACT

Lossy compression is now increasingly used due to the enormous amount of images gathered by airborne and satellite sensors. Nevertheless, the implications of these compression procedures have been scarcely assessed. Segmentation before digital image classification is also a technique increasingly used in GEOBIA (GEOgraphic Object-Based Image Analysis). This paper presents an object-oriented application for image analysis using color orthophotos (RGB bands) and a Quickbird image (RGB and a near infrared band). We use different compression levels in order to study the effects of the data loss on the segmentation-based classification results. A set of 4 color orthophotos with 1 m spatial resolution and a 4-band Quickbird satellite image with 0.7 m spatial resolution each covering an area of about $1200 \times 1200\ m^2$ (144 ha) was chosen for the experiment. Those scenes were compressed at 8 compression ratios (between 5:1 and 1000:1) using the JPEG 2000 standard.

There were 7 thematic categories: dense vegetation, herbaceous, bare lands, road and asphalt areas, building areas, swimming pools and rivers (if necessary). The best category classification was obtained using a hierarchical classification algorithm over the second segmentation level. The same segmentation and classification methods were applied in order to establish a semi-automatic technique for all 40 images.

To estimate the overall accuracy, a confusion matrix was calculated using a photointerpreted ground-truth map (fully covering 25% of each orthophoto). The mean accuracy over non-compressed images was 66% for the orthophotos and 72% for the Quickbird image. It is interesting to obtain this medium overall accuracy to be able to properly assess the compression effects (if the initial overall accuracy is very high, the possible positive effects of compression would not be noticeable). The first and second compression levels (up to 10:1) obtain results similar to the reference ones. Differences in the third to fifth levels (20:1 to 100:1) were moderate to large (accuracies 61–58% for orthophotos and 67–65% for Quickbird), while more compressed images obtained the worst results (accuracies lower than 55%). As a comparison, the usual independent test areas (covering a small percentage of the classified area) were also used. The results show that this classification evaluation approach must be used with caution because it may underestimate the classification errors.

1. Introduction and objectives

The total amount of data generated by remote sensing (RS) platforms is increasing every day. Even though the commercial providers have a large structure to store all this information, users do not often have access to this structure, and thus data management problems arise. The new paradigm of Spatial Data Infrastructures (SDIs) promotes the establishment of web data services, usually in terms of Open Geospatial Consortium (OGC) standards like the Web Map Service (WMS), the Web Coverage Service (WCS) (Maguire and Longley, 2005) or the recent Web Map Tile Service (WMTS, Masó et al., 2010). However, it is necessary to use compression and interactive transmission strategies in these web services in order to transfer images (which may be very large in the case of WCS) repetitively to environments with restricted bandwidth.

In disaster or emergency management environments, and especially in a crisis situation, image compression techniques are crucial for sending this very important data efficiently and quickly to the reaction teams, who normally use laptop computers and mobile devices. In this context, high-resolution satellites like GeoEye and QuickBird, and medium resolution satellites, such as the two generations of the Disaster Monitoring Constellation (DMC) (DMC

* Corresponding author at: Geography Department, Despatx B9-1092, Edicifi B, Facultat de Filosofia i Lletres, Campus de la Universitat Autònoma de Barcelona, 08193, Cerdanyola del Vallès, Barcelona, Spain. Tel.: +34 935 811 527; fax: +34 935 812 001.
E-mail address: Alaitz.Zabala@uab.cat (A. Zabala).

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International Imaging, 2005–2007), are able to capture images anywhere in the world and quickly provide imagery for disaster emergencies. Using semi-automatic or automatic classification methods of images could allow users to assess the damage and act quickly.

Image classification has traditionally employed pixel-based methods based on statistical measurements of individual pixel values to classify each pixel with supervised, unsupervised or hybrid classifiers (Xiaoxia et al., 2005; Wuest and Zhang, 2009; Serra et al., 2009). Nevertheless, with the improvement in spatial resolution of remote images (such as the obtained from digital airborne cameras or from high resolution satellite sensors), the number of articles on GEOBIA (GEOgraphic Object-Based Image Analysis) techniques has increased (Blaschke, 2010). In fact, a sign of the growing importance of this area is that, since 2006, there have been biennial international conferences covering this topic. In this case, image classification needs groups of pixels selected as objects, and therefore the segmentation process is necessary to obtain these objects, and is the first step in the classification process (Conchedda et al., 2008; Ke et al., 2010). There are different approaches to segmentation and classification. In this study we use Definiens algorithms (Baatz et al., 2004).

In recent years, a set of lossy compression techniques based on different algorithms has appeared (discrete cosine transform, DCT, discrete wavelet transform, DWT, etc.). In this paper we study widely used compression standards and aim to evaluate the implication of image lossy compression on object based classifications, as there are few quantitative analyses of this approach for compressing data. It is important to bear in mind that we are always dealing with lossy compression algorithms, which sacrifice part of the data in order to achieve a higher compression ratio but sometimes with no appreciable loss of image quality (Kiema, 2000; Zabala et al., 2007).

In the field of RS, and in spite of the spectacular compression ratios reached, there has been little quantitative analysis about the implications of these compressions on image applications. Image lossy compression modifies the image and thus it will affect the classification, but previous literature is not conclusive with the obtained results, especially in the context of object-based classifications methods applied to high resolution imagery. Some authors found that the information loss is not always relevant for the classifier (thus the overall accuracy is maintained) (Kiema, 2000; Carvajal et al., 2008) or even that medium compressions are positive for the classifier (increasing the overall accuracy of the classifications) (Zabala et al., 2006; Choi et al., 2008; Zabala and Pons, 2011). Unfortunately, these last papers do not use object-based classifications over high resolution images (i.e., the usual scenario for emergency management environments). Even if server-based processing (WPS in OGC terms) is used to classify the original (uncompressed) images on a server, the effect of compression on classification is still an open issue, considering the increasingly use of on-board satellite compression. According to Yu et al. (2009), several instruments, such as the ones onboard Ikonos-2, QuickBird-2, Proba-1 or any of the 5 from the RapidEye constellation, are already using lossy on-board compression.

The main aim of this paper is to assess the impact of compression on the segmentation-based classification results. Therefore, the conclusions of this study show how compression affects the segmentation and classification processes. Moreover, we will also discuss the feasibility of this approach (segmentation over compressed images) in an emergency management environment, and the different conclusions obtained when ground-truth layers or independent test sites in a reduced area percentage are used. See Fig. 1 for a general overview of the experimental design.

2. Methods

2.1. Study area and material

Aerial color orthophotos (with three bands: red, green and blue or RGB) are traditionally one of the most common products generated for cartographic institutes to be used as reference cartography for land management. It is important to note that working with only 3 bands from the visible spectrum makes it difficult to obtain an optimal classification due to the limited input information. However, this kind of orthophoto is widely used because most of the institutional map servers offer free RGB orthophoto download or WMS geoservices. The acquisition of a near infrared band brings a higher potential to easily discriminate among some covers that are hardly discernible without this information.

This paper uses several RGB orthophotos and one Quickbird 4-band image (including near infrared, NIR, and RGB bands) to asses the improvement on the GEOBIA classifications due to NIR information (that is likely to increase the initial overall accuracy) and, especially, to study whether the impact of compression is related to the fitness of the initial material to be classified (i.e., with or without an infrared band, in this case). The Quickbird image was used because, in the context of an emergency event, it is likely that satellite images like this one will be used.

2.1.1. Aerial RGB orthophotos

A set of 4 aerial RGB orthophotos was selected: 3 orthophotos over Catalonia (NE Spain) and the other one over Navarre (N Spain) (see Fig. 2). More specifically, in Catalonia we selected areas in Sant Cugat del Vallès, Vallvidrera and Olot, and in Navarre, we selected an area in Zizur Mayor. These 4 orthophotos (see Fig. 3) were selected because of their similar urban landscape, characterized by low density urban areas with a significant number of swimming pools, gardens, forested areas and field crops. However, there are some differences among the images: in two of them (Vallvidrera and Sant Cugat) the predominant urban structure is detached houses, while in the other two more semi-detached and multi-family houses are present.

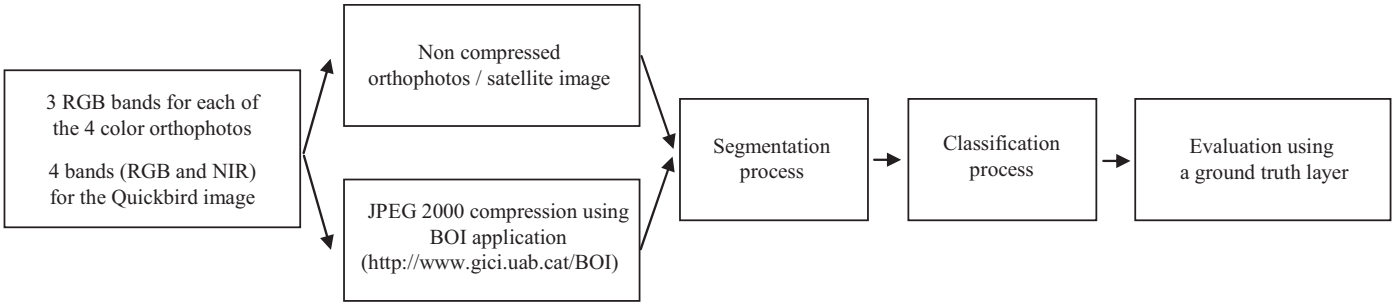

Fig. 1. Overview of the experimental design.