EVALUATION OF SATELLITE IMAGE SEGMENTATION USING SYNTHETIC IMAGES

ABSTRACT

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1. INTRODUCTION

The number of high and very high spatial resolution images acquired by Earth Observation Satellites (EOS) has increased considerably in recent years. One of the most challenging tasks in Remote Sensing at present is how to handle the huge amounts of image data made available, in order to extract meaningful information. The traditional pixel based approach, treating each image pixel individually without regard to its location in the image, is not a satisfactory approach, for at least two reasons:

(1) the context information of a pixel (its neighbourhood) is ignored;

(2) the pixel is not considered to be a "natural" element, or a true geographical object [1], of an image scene.

It has been recognised that the satellite image classification accuracy can be improved by modelling the spatial interaction between pixels, using Markov Random Field models [2]. Another alternative to the standard per-pixel analysis of multi-spectral EOS images is the so called the Object-Based Image Analysis (OBIA) approach. Instead of focusing on individual image pixels, the OBIA approach consists of partitioning an image into meaningful image-objects, based on the similarity of neighbouring pixels. A common element of all OBIA systems is the segmentation stage, where the image is partitioned in a number of objects (or segments). The segmentation is a critical stage of the OBIA process because if it fails to identify as an object a given element present in the image, the subsequent stages will generally be unable to recognise (or classify) this element.

The evaluation of the segmentation stage is an important, yet often neglected, aspect of the OBIA systems. The main reason for this is the lack of a practical standard procedure for the evaluation of the segmentation results produced for EOS images [3]. The general process for segmentation evaluation is based on discrepancy measures between the segmentation result and a reference [4], but it is usually difficult to have abundant reference segmentation data in the case of EOS images.

The purpose of this work is to test if the Synthetic Image TEsting Framework (SITEF) [5] is an effective alternative, for EOS images, to the standard evaluation based on the identification of reference parcels (objects).

2. METHODOLOGY

The SITEF evaluation of image segmentation results is based on the production of multi-spectral synthetic images with the spectral characteristics extracted from a signature EOS image [5]. The knowledge of the shape and location of the objects in the synthetic image provides a reference, allowing for a quantitative evaluation of the segmentation results. The method was first presented in [5], using the Hammoude metric and the Rand, Corrected Rand and Jaccard external similarity indices. An improvement of the synthetic image generation process was presented in [6], to include adjacency effects between neighbouring parcels.

Using SITEF, the evaluation of segmentation results can be done with three different perspectives:

(1) for the various parameter settings used in the segmentation algorithm,

(2) for the different parcel sizes and shapes,

(3) for the different land cover types (or spectral signatures) and sets of land cover types.

A SPOT HRG satellite image was used for the practical test carried out. The image covers a rural area of Poland, where 6 land cover types were identified (A – coniferous forest, B – deciduous forest C – mown grassland, D – non-mown grassland, E – gardens, F – clear cuts). A total of seven synthetic images were produced – one using all 6 classes, and six other using all 5-class sub-sets. Each synthetic image has 1600 parcels, from 1 by 1 to 8 by 8 units, with an unit of 3 by 3 pixels. Figure 1 shows the near infrared spectral band of the satellite (signature) image with the training areas for the six land cover types tested, as well as one of the synthetic images created with 5 classes (RGB colour composite of SPOT HRG bands 123).

The original satellite image and the synthetic images created were all segmented using the multi-resolution algorithm in Definiens 7 software, with various parameter settings [7]. The segmentation results provided by the segmentation software were compared with the expected (ideal) segmentation, using the Hammoude metric [5] for the 1600 parcels (objects) on each synthetic test image. A number of land parcels were also identified (manually) in the satellite image, to be used as reference.

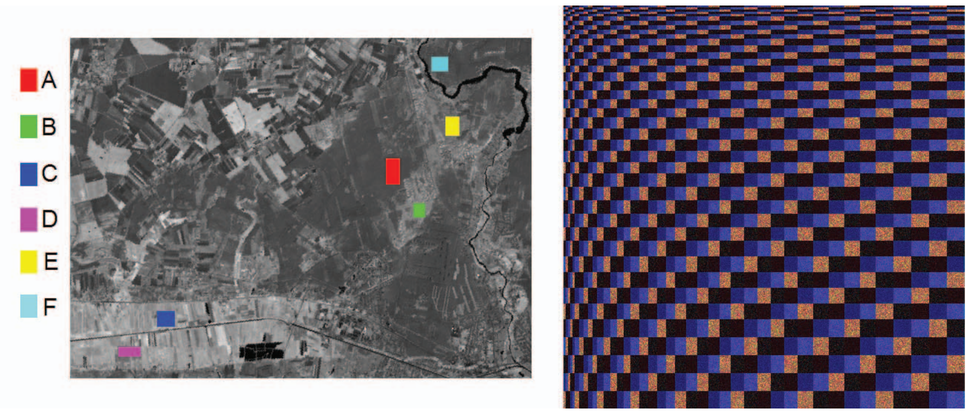

Fig.1 – Satellite signature image with 6 land cover types (left) and synthetic image for 5 classes (right)

3. PRELIMINARY RESULTS

The segmentation evaluation can be done through multiple perspectives, such as: parcel size and shape, the land cover type of a parcel and its neighbouring, and for the various parameter settings used in the segmentation algorithm. The segmentation results vary considerably with the parameter settings, as illustrated in figure 2 for a section of the satellite image, segmented with different parameter values (S–Scale, C–Compactness).

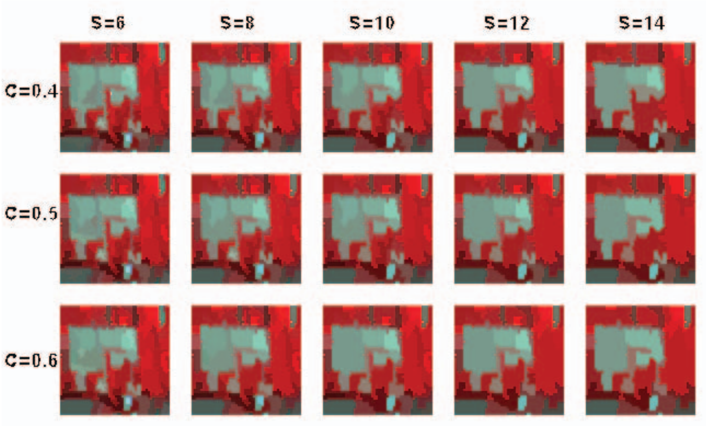

Fig.2 Segmentation results for a section of the satellite image, with different values for parameters S and C.

A fraction of the synthetic image segmentation results is presented in figure 3, where the average Hammoude value (H) for sets of parcels with a common characteristic is plotted as a function of the segmentation algorithm parameter S (Scale), with the other parameters fixed (default values). The values of H presented are in a range 0-100, with 0 corresponding to a perfect result (exact match between segmentation and reference). The first plot (left) shows the average H for all parcels with the same land cover type, as a function of S. The second plot shows the average H for parcels of nearly the same area (15 or 16 square units) but different shapes (4x4, 3x5 and 2x8 units). These results were computed for the synthetic image 5D (5 classes, all except D). The best choice for S depends both on the land cover type and on the parcel shape, as can be observed in the plots in Figure 3.

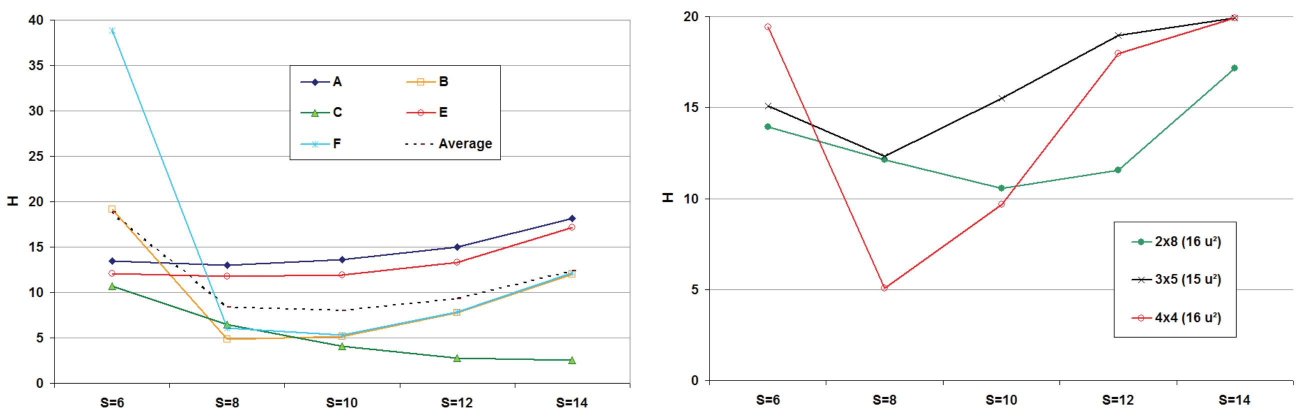

Fig.3 Average H for different values of S, for fixed land cover type (left) and parcel size and shape (right).

4. CONCLUSIONS AND FURTHER WORK

The evaluation of satellite image segmentation results based on synthetic images offers obvious advantages. A large number of parcels is made available to evaluate the performance of the segmentation method, providing multiple perspectives for the evaluation – e.g. parcel size, shape, land cover type, neighbourhood parcels. The main disadvantage is that currently only rectangular shapes are used. However, the alternative using reference parcels identified on a EOS image is a laborious process and provides very limited possibilities for evaluation.

The results from the evaluation based on parcels (objects) manually identified in the satellite image are currently under way. The main problem is the limited number of parcels (at the moment 8 for each class) and the difficulty in evaluating the impact of parcel size, shape and neighbourhood in the segmentation, as the full range of features is generally not present in real EOS images. The preliminary results indicate that for some land cover types the results are acceptable, but for others there seems to be a poor match between the segmentation results and the references, for most segmentation parameter settings tested.

5. REFERENCES

[1] G.J. Hay, G. Castilla, M.A. Wulder, J.R. Ruiz, "An automated object-based approach for the multiscale image segmentation of forest scenes", *International Journal of Applied Earth Observation*, Elsevier, Vol. 7, pp. 339–359, 2005.

[2] B.C.K. Tso, P.M. Mather, "Classification of multisource remote sensing imagery using a genetic algorithm and Markov random fields", *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 37, 1255-1260, 1999.

[3] Neubert, M., H. Herold, G. Meinel, "Assessing Image Segmentation Quality Concepts, Methods and Application", In: Blaschke, T.; Hay, G. & Lang, S. (Eds.): Object-Based Image Analysis – Spatial concepts for knowledge-driven remote sensing applications, Springer, Berlin, pp. 769-784, 2008

[4] A.P. Carleer, O. Debeir, E. Wolff, "Assessment of very high spatial resolution satellite image segmentations", *Photogrammetric Engineering and Remote Sensing*, ASPRS, Vol. 71, pp. 1285-1294, 2005.

[5] A.R.S. Marçal, A. Rodrigues, "A method for multi-spectral image segmentation evaluation based on synthetic images", *Computers & Geosciences*, Vol. 35, 1574-1581, 2009.

[6] A.R.S. Marçal, A. Rodrigues, M. Cunha, "The Synthetic Image TEsting Framework (SITEF) for the evaluation of multi-spectral image segmentation algorithms", IEEE IGARSS 2009 Proceedings, (in press).

[7] DEFINIENS, "Definiens Developer 7 User Guide", 2008