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Avaliação quantitativa da segmentação de imagens de sensoriamento remoto - conceitos e mais resultados

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Abstract. Primarily due to the progresses in spatial resolution of satellite imagery, the methods of segment-based image analysis for generating and updating geographical information are becoming more and more important. In the studies of Neubert and Meinel (2003), Meinel and Neubert (2004) and Neubert et al. (2006) the capabilities of available segmentation programs for high resolution remote sensing data were assessed and compared. This paper intends to update the preceding studies by considering recently available software. The achieved segmentation quality of each program is evaluated on the basis of an empirical discrepancy method using pan-sharpened multi-spectral IKONOS data. Furthermore, an overview of methods for quantitative image segmentation quality evaluation is given. The stated results provide an approach to determine each program's performance and appropriateness for specific segmentation tasks.

Palavras-chave: image segmentation, remote sensing, evaluation, quality, segmentação de imagens, sensoriamento remoto, avaliação, qualidade.

1. Introduction

Image objects in remotely sensed imagery are often homogeneous and can be delineated by segmentation. Thus, the number of elements as a basis for a following image classification is significantly reduced. The quality of classification is directly affected by segmentation quality. Hence the quality assessment of segmentation is within the main focus of this study on different presently available segmentation software. Recent investigations have shown that a pixel-based analysis of such high resolution imagery has explicit limits. Using segmentation techniques some problems of pixel-based image analysis could be overcome (e.g. Meinel et al., 2001). Feature extraction programs, which perform selective image segmentation, will not be considered in this study.

2. Evaluated Segmentation Software

There is a large variety of implemented segmentation algorithms using very different concepts. For the evaluation only approaches were considered that are able to perform a full (so-called multi-region) image segmentation in an operational way. Furthermore, the choice of approaches was based on the suitability to segment remote sensing imagery. In addition to the results presented in Meinel and Neubert (2004) and Neubert et al. (2006), the following algorithms and programs have been evaluated:

- *HalconSEG* (Adapted *Lanser*-segmentation algorithm for HALCON, MVTec GmbH, Munich, Germany, ***planned update***);
- *Imagine WS* for Erdas Imagine (Austrian Academy of Sciences, Vienna, Austria);
- *PARBAT* (International Institute for Geo-Information Science and Earth Observation, Enschede, Netherlands);
- *RHSEG* (NASA, Goddard Space Flight Center, Greenbelt, MD, USA, ***update available***);
- *SEGEN* (IBM Haifa Research Labs, Haifa, Israel);

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- *SegSAR* (National Institute for Space Research, São José dos Campos, Brazil);
- *InfoPACK* (Merseyside, United Kingdom ***new results for updated software available***)
- *SCRM* (Calgary, Canada, ***new software, results available***)
- *Feature Analyst* (Missoula, MT, USA, ***waiting for software***)

3. Evaluation Methods

3.1 Approaches to Quantitative Segmentation Evaluation

Table 1 provides an overview to recently proposed quantitative evaluation methods within the classification framework given in Zhang (1996).

Evaluation Approach / Reference	Method Type[1]	Equation	Description
Fragmentation *(FRAG)* Strasters and Gerbrands (1991)	ED	$FRAG = \frac{1}{1 + p \cdot \lvert T_N - A_N \rvert^q}$ where T_N is the number of objects in the image and A_N the number of regions in the reference; *p* and *q* are scaling parameters	addresses over-/under-segmentation by analysing the number of segmented and reference regions
Area-Fit-Index *(AFI)* Lucieer (2004)	ED	$AFI = \frac{A_{\text{reference object}} - A_{\text{largest segment}}}{A_{\text{reference object}}}$	
Geometric features Circularity Yang et al. (1995)	ED	$Circularity = \frac{4\pi A}{P}$ where *A* is the area and *P* is the perimeter	addresses the shape conformity between segmentation and reference regions (scaling invariant shape feature)
Geometric features Shape Index Neubert and Meinel (2003)		$ShapeIndex = \frac{P}{4\sqrt{A}}$ where *A* is the area and *P* is the perimeter	
Empirical Evaluation Function Borsotti et al. (1998)	EG	$Q(I) = \frac{1}{1000(N \cdot M)} \sqrt{R} \sum_{i=1}^{R} \left[\frac{e_i^2}{1 + \log A_i} + \left(\frac{R(A_i)}{A_i} \right)^2 \right]$ where $N \cdot M$ is the size of the image *I*, e_i is the colour error of the region *i* and *R(A)* the number of regions of the size *A*	addresses the uniformity feature within segmented regions (colour deviation)
Entropy-based evaluation function and a weighted disorder function Zhang et al. (2004)	EG	$E = H_l(I) + H_r(I)$ where H_l is the layout entropy and H_r is the expected region entropy of the image *I*	addresses the uniformity within segmented regions (luminosity) using the entropy as a criterion of disorder within a region
Fitness function Everingham et al. (2002)	A, ED	Probabilistic hull, Potential accuracy *f(a,I)* Multidimensional fitness-cost-space	addresses multiple criteria and para-meterizations of algorithms by a probabilistic Fitness/Cost Analysis

[1] according to classification proposed in Zhang (1996): Analytical (A), Empirical Goodness, unsupervised (EG), Empirical Discrepancy, supervised (ED)

Table 1. Approaches to quantitative evaluation of segmentation results.

3.2 Applied Evaluation Method

According to the procedure proposed in Neubert and Meinel (2003) firstly all results came under an overall visual survey. General criterions, like the delineation of varying land cover types (e. g. meadow/forest, agriculture/meadow, etc.), the segmentation of linear objects, the occurrence of faulty segmentations and a description of the overall segmentation quality were in the focus of this first step. Furthermore, a detailed comparison based on visual delineated and clearly definable reference areas was carried out. Therefore 20 different areas (varying in location, form, area, texture, contrast, land cover type etc.) were selected and each was visually and geometrically compared with the segmented pendants. The geometrical comparison is a combination of morphological features (area *Ai*, perimeter *Pi*, and Shape Index *SIi*)

$$SI_i = \frac{P_i}{4\sqrt{A_i}} \qquad (1)$$

of the region *i* and the number of segments or partial segments in the case of over-segmentation. The Shape Index comes from landscape ecology and addresses the polygon form. For all features the variances to the reference values were calculated. As partial segments all polygons with at least 50 % area in the reference object were counted. Additionally the quality of segmentation was visually rated (0 poor, 1 medium, 2 good). A good segmentation quality is reached, when the overall differences of all criteria between the segmentation results and the associated reference objects are as low as possible.

4 Results and Discussion

The overall results are cumulated and compared in table 2. SegSAR, HalconSEG and Imagine WS are reaching the best average region conformity (lowest Shape Index differences), whereas SEGEN shows the best visual result.
- work in progress as results or software updates are just available -

5. Conclusions

Image segmentation offers an important approach to semi-automated image analysis. Particularly in combination with presented evaluation methods and existing GIS-data image segmentation algorithms already are indispensable resources to retrieve geo-information from remote sensing imagery.
In combination with the previous study in total 16 segmentation programs have been evaluated. Is has been shown, that there is more than one interesting approach in this dynamic field of research. The evaluation will be continued. Furthermore, it is planned to extend the quality assessment procedure itself by some of the presented evaluation methods. The evaluation is still open for further algorithms.

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