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A Segmentation Algorithm Based on an Iterative Computation of the Mean Shift Filtering

Roberto Rodríguez · Ana G. Suarez · Juan H. Sossa

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Abstract Image segmentation is accepted to be one of the most important problems in image analysis. The good performance of any recognition system strongly depends on the results provided by the segmentation module. According to many researchers, segmentation finishes when the goal of observer is satisfied. Experience has shown that the most effective methods continue to be the iterative algorithms. However, a problem with these algorithms is the stopping criterion. In this work, we present a strategy for image segmentation through a new algorithm based on recursively applying the mean shift filtering, where entropy is used as a stopping criterion. The main feature of the proposed algorithm is to carry out segmentation in an only step. In other words, with the new algorithm is not necessary to carry out additionally the segmentation step, where in many occasions (mainly in complex applications), it can be computationally expensive. The effectiveness of the proposed algorithm is shown through several experimental results. The obtained results proved that the proposed segmentation algorithm is a straightforward extension of the filtering process. In this paper a comparison between our algorithm and so called *EDISON* System was carried out.

Keywords Entropy · Image segmentation · Mean shift · Smoothing filter

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Optimized Mean Shift Algorithm for Color Segmentation in Image Sequences

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ABSTRACT

The application of the mean shift algorithm to color image segmentation has been proposed in 1997 by Comaniciu and Meer. We apply the mean shift color segmentation to image sequences, as the first step of a moving object segmentation algorithm. Previous work has shown that it is well suited for this task, because it provides better temporal stability of the segmentation result than other approaches. The drawback is higher computational cost.

For speed up of processing on image sequences we exploit the fact that subsequent frames are similar and use the cluster centers of previous frames as initial estimates, which also enhances spatial segmentation continuity. In contrast to other implementations we use the originally proposed CIE LUV color space to ensure high quality segmentation results. We show that moderate quantization of the input data before conversion to CIE LUV has little influence on the segmentation quality but results in significant speed up. We also propose changes in the post-processing step to increase the temporal stability of border pixels.

We perform objective evaluation of the segmentation results to compare the original algorithm with our modified version. We show that our optimized algorithm reduces processing time and increases the temporal stability of the segmentation.

Keywords: segmentation, mean shift, image sequence, objective evaluation

1. INTRODUCTION

The application of the mean shift algorithm to color image segmentation has been proposed in 1997 by Comaniciu and Meer [2]. Since then it has become a widely used method for color image segmentation, as it provides significantly better segmentation results as other approaches (e.g. the Watershed algorithm), for example less oversegmentation and robustness against illumination changes.

We apply the mean shift color segmentation to image sequences, as the first step in a moving object segmentation algorithm. Previous work has shown that the mean shift algorithm is well suited for segmentation of image sequences, because it provides better temporal stability of the segmentation result than other approaches (cf. for example [6]). However, the drawback is that the mean shift algorithm is computationally more expensive, and computational costs are even more an issue when the algorithm is applied to image sequences. This means that there is need for optimization in order to use the algorithm in applications where performance is an issue.

One obvious optimization is to exploit the temporal redundancy in the image data when applying the algorithm to image sequences. It can be expected that the algorithm converges faster. This optimization has already been mentioned in [8] and [9]. Other researchers advocated the use of another color space than CIE LUV to reduce the complexity of the algorithm, for example, YUV [9] or HSV [10] have been proposed. Another reported optimization avoids applying the mean shift procedure to pixels that lie on the mean shift trajectory of other similar pixels which have already been processed [1]. The hierarchical mean shift proposed in [5] has been proposed to reduce complexity in spatio-temporal

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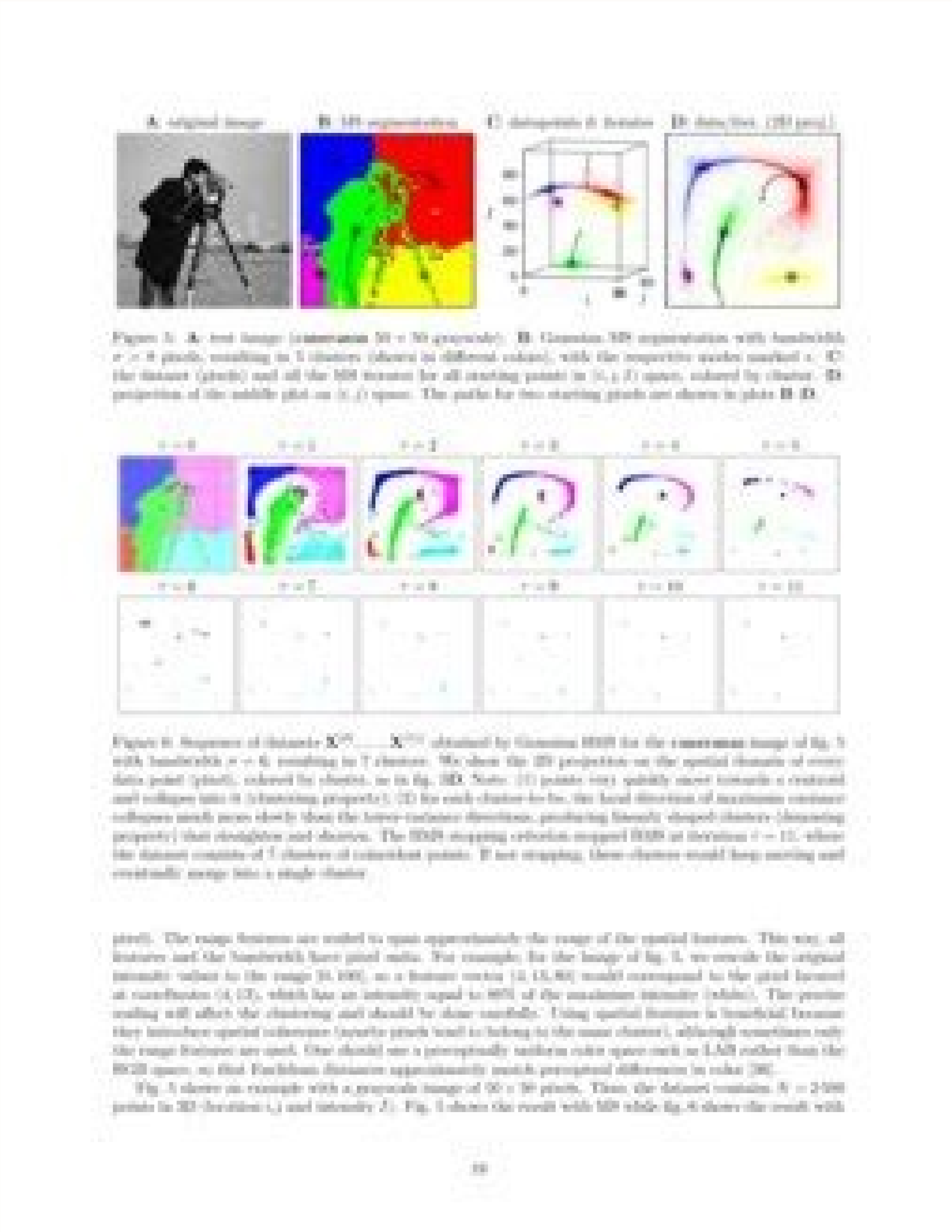

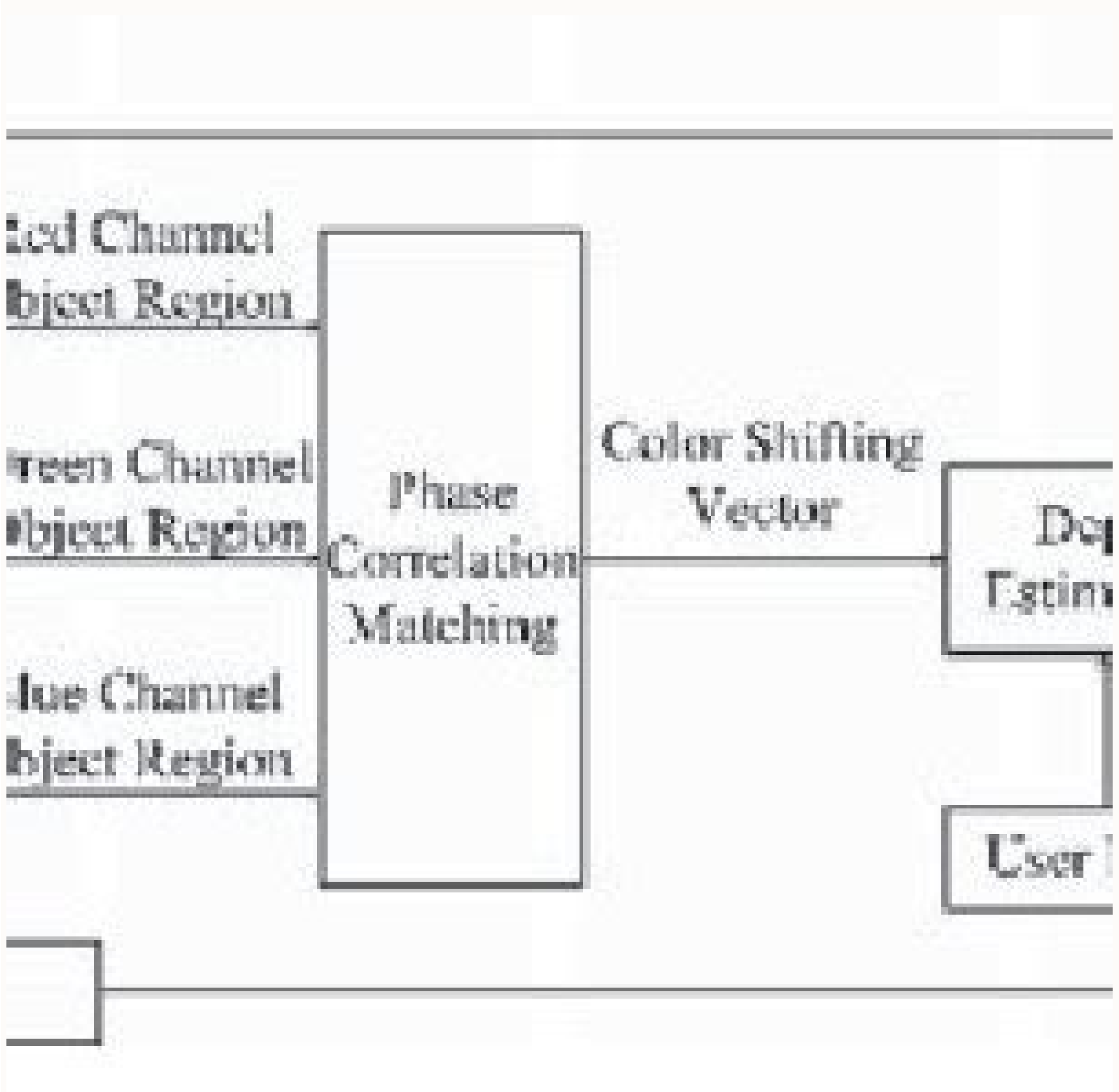

Semivariogram-Based Spatial Bandwidth Selection for Remote Sensing Image Segmentation With Mean-Shift Algorithm

Dongping Ming, Tianyu Ci, Hongyue Cai, Longxiang Li, Cheng Qiao, and Jinyang Du

***Abstract*—Image segmentation is a key procedure that partitions an image into homogeneous parcels in object-based image analysis (OBIA). Scale selection in image segmentation is always difficult for high-performance OBIA. This letter is aimed at scale selection before segmentation in OBIA and proposes a spatial statistics-based spatial bandwidth selection method based on mean-shift segmentation. This study uses Ikonos and Quickbird panchromatic images as the experimental data and then computes their semivariances to select the optimal spatial bandwidth for mean-shift segmentation. To validate this method and interpret the relationship between the semivariances and segmentation scale, this letter implements an image segmentation evaluation based on the homogeneity within and the heterogeneity between the segmentation parcels. The evaluation results basically support the proposed scale selection method based on the semivariogram. Consequently, the semivariogram-based spatial bandwidth selection method is practically meaningful for pre-estimating the appropriate scale and thus contributes to improving the performance and efficiency of OBIA.**

***Index Terms*—Evaluation of segmentation, high-spatial-resolution remote sensing image, mean-shift segmentation, semivariogram, spatial bandwidth selection.**

I. Introduction

WITH the increase of spatial resolution in remote sensing images, misclassification and broken patches become more of an issue for pixel-based multispectral image classifications. Object-based image analysis (OBIA) can effectively incorporate spatial information and expert knowledge into the classification, and the classified image objects are useful links to integrate remote sensing and geographic information systems. Multiscale image segmentation is the foundational procedure of OBIA in which the digital image is transformed from discrete pixels into homogeneous image object primitives. The selection of scale parameter in the segmentation is the key to OBIA because an inappropriate scale will lead to oversegmentation or insufficient segmentation, which will directly reduce the accuracy and efficiency of multiscale information extraction.

Currently, several multiscale segmentation algorithms have been proposed and applied in remote sensing image analysis, including watershed segmentation, multiresolution segmentation [1], and mean-shift segmentation [2], [3]. Among these algorithms, watershed segmentation has a specific scale parameter; however, the relationship between segmentation results on different scales cannot be easily determined. Multiresolution segmentation is based on the so-called fractal net evolution approach [1], [4], and it not only provides a scale parameter but also incorporates the hierarchical relationship between different levels. However, the scale parameter is an abstract value used to determine the maximum possible change of heterogeneity caused by fusing several objects, and it is difficult for a user to quantitatively select the optimal scale parameter without repetitious tests because the details of the algorithm are commercially secret and unpublished.

The mean-shift segmentation algorithm, however, has the advantages of a specific scale parameter and a hierarchical relationship between segmentation levels. Therefore, this letter adopts the mean-shift multiscale segmentation algorithm to extract the homogenous parcels. In addition, the essence of determining the optimal scale parameters is the statistical pre-estimation of global and local structures of the original image, which is particularly true in remote sensing application based on multiscale segmentation. By combining the theories of classical geospatial statistics and pattern recognition, this letter proposes an optimal spatial bandwidth selection method based on a semivariogram for mean-shift image segmentation.

II. Multiscale Segmentation Based on Mean-Shift Algorithm

Mean shift is a robust and adaptive clustering algorithm with nonparametric density estimation [5], [6]. This algorithm does not require *a priori* knowledge of the number of clusters, and it can shift the points in the feature space to the local maxima of the density function by effective iterations. Additionally, the multiscale segmentation of high-spatial-resolution images is available by employing the mean-shift algorithm with different bandwidths and a different merging rule. For further details, please refer to [3].

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