Computers and Electrical Engineering 000 (2017) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

A novel active contour model based on median absolute deviation for remote sensing river image segmentation☆

Bin Han[a,*], Yiquan Wu[a,b,c,d,e], Yu Song[a]

[a] School of Electronic and Information Engineering, Nanjing University of Aeronautics and Astronautics, Jiang Jun Road, No 29, Nanjing, 211106, China
[b] Engineering Technology Research Center of Wuhan Intelligent Basin, Changjiang River Scientific Research Institute, Changjian Water resources Commission, Wuhan, 430010, China
[c] Key Laboratory of Yellow River Sediment of Ministry of Water Resources, Yellow River Institute of Hydraulic Research, Yellow Water resources Commission, Zhengzhou, 450003, China
[d] Key Laboratory of Port, Waterway and Sedimentation Engineering of the Ministry of Transport, Nanjing Hydraulic Research Institute, Nanjing, 210024, China
[e] State Key Laboratory of Urban Water Resources and Environment, Harbin Institute of Technology, Harbin, 150090, China

ARTICLE INFO

Article history:
Received 4 August 2016
Revised 6 April 2017
Accepted 6 April 2017
Available online xxx

Keywords:
Remote sensing river image
Image segmentation
Median absolute deviation
Active contour model
Region energy weights

ABSTRACT

Aiming at the problem of the inaccurate segmentation of remote sensing river images by existing active contour models (ACMs), a novel ACM based on median absolute deviation for remote sensing river image segmentation is presented. Firstly, the external energy constraint terms of the presented model are defined by the median absolute deviation instead of the within-cluster variance in the Chan–Vese (CV) model. Secondly, in order to accelerate the evolution of the model, the fusion information of within-cluster variances and median absolute deviations of pixel grayscale values inside the object and background regions is utilized as the region energy weights. The corresponding experiments are carried out on a large number of remote sensing river images and the results illustrate that the presented model outperforms the existing ACMs, which can segment the remote sensing river images much more accurately and efficiently.

1. Introduction

The detection and identification of rivers from remote sensing images are of great practical significance to the investigation of water area circumstance, the planning of water channel, the prevention of flood and waterlogging, and the construction of water conservancy facilities. Synthetic aperture radar remote sensing imaging has become one of the main approaches of detecting and identifying rivers since it has several following advantages. First, it has a very wide imaging range. Second, the obtained images are clear. Besides, the imaging is not subject to weather and time constraints. Image segmentation is the key to using the above remote sensing images to detect and identify the river, therefore it is greatly essential to study the segmentation of remote sensing river images.

The active contour model (ACM) is a new class of methods in the field of image segmentation. The advantages of ACM are as follows: It is easily modeled with efficient calculation and simple implementation. Moreover, it is not constrained by

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. A. H. Mazinan.
* Corresponding author.
E-mail addresses: 909907566@qq.com (B. Han), nuaaimage@163.com (Y. Wu), 519559374@qq.com (Y. Song).

http://dx.doi.org/10.1016/j.compeleceng.2017.04.005
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the shape of the object. Therefore, the ACM has been gradually applied to the remote sensing river image segmentation. The ACMs are generally divided into three classes relying on the form of the evolution: the edge-based models [1–5], the region-based models [6–10], and the hybrid models [11–15]. The edge-based models draw upon the edge information of the image as the force to make the active contour curve move towards the object edges. The region-based models draw upon a specific regional description criterion to measure the differences of the pixel grayscale values inside each region, which can perform the evolution of the model. The hybrid models combine the previous two classes of models and their evolutions rely on both the gradient magnitude and the intensity differences of the image. The geodesic active contour (GAC) model [16] which is one of the most classic edge-based ACMs guides the evolution of the active contour through an edge detection function and the active contour finally stops at the object edges with high gradient. The edge-based models have clear drawbacks that the position and the shape of the initial contour have a great effect on the curve evolution. In addition, their evolutions depend heavily on the gradient magnitude of the image. In the case that the image edge information is very complex, the edge-based models are always difficult to converge, resulting in the failure of the image segmentation. In order to address the drawbacks of the edge-based models, the researchers presented another class of ACMs, namely the region-based models. The representative region-based model is Chan–Vese(CV) model [17]. It considers the segmented image generally consists of two homogeneous regions, namely the object region and the background region. The contour curve is driven to the edges of the object by calculating the differences of the pixel grayscale values inside the object and background regions. The evolution of the CV model does not rely on the gradient magnitude of the image, thus it is able to well cope with the image in the presence of weak edges. However, there are some disadvantages of the CV model. The convergence rate of the CV model is relatively slow and the iteration number is relatively large. Li et al. [18] presented a local binary fitting active contour model (LBF). The LBF model calculates the local intensity characteristics information of the image utilizing the Gaussian kernel function to guide the curve evolution, which can overcome the disadvantage of the CV model, i.e. its incapability to cope with the image with inhomogeneous content. When the local intensity characteristics of the image is too complex, the final segmented image of the LBF model is not ideal. In each iteration of the model, the convolution operation is needed and the computational complexity is too high, leading to the low segmentation efficiency. Zhang et al. [19] presented an ACM with local image fitting energy (LIF). The LIF model also draws upon the local grayscale value information of the image to drive the curve evolution, therefore it can solve the problem of segmenting the image with inhomogeneous content. Compared with the LBF model, there is no need to perform the convolution operation in the iterative process. Instead, the convolution of the original image with the Gaussian kernel function is done before the iteration. Thus, the LIF model has the lower computation cost and its segmentation efficiency is improved to a large extent. The position and the shape of the initial contour have slight effect on the curve evolution of the region-based models and their evolutions do not rely on the edge characteristics of the image. The hybrid models combine the region intensity characteristics and the edge gradient characteristics of the image, therefore the fusion information is utilized to guide the curve evolution. Tian et al. [20] presented a hybrid ACM which is actually the combination of the CV model and the GAC model (CGACM). It synthesizes the internal normal vector in the GAC model and the regional differences in the CV model to drive the active contour to move towards and eventually stop at the edges of the object. Ge et al. [21] presented another hybrid model with structured feature (SFACM). It combines the structured gradient vector flow method and the CV model. Meanwhile, the edge information is also incorporated into the object function of the model. The hybrid models can cope with the image in the presence of weak edges and the position and shape of the initial contour have little effect on their final segmented images. However, they can not handle the inhomogeneous regions well. Roughly speaking, the above three categories of active contour models have their advantages and disadvantages.

The local information of the remote sensing river image is very complex and there are a few interference regions inside its background. Therefore, it is difficult to segment the remote sensing river image using the edge-based models. Similarly, the hybrid models can not perform the segmentation. Compared with the above two categories of active contour models, the region-based models can obtain better segmented images and be applicable to the segmentation of the remote sensing river image. However, most of the existing region-based models use the within-cluster variances of the pixel grayscale values inside object and background regions to describe the differences of the pixel grayscale values inside object and background regions. In addition, they use the means of pixel grayscale values inside object and background regions as the region fitting centers, which is obviously unreasonable. The grayscale values of the interference region are directly involved in the calculation of the region fitting center, which will affect the calculation accuracy of the region fitting center. Moreover, the differences between the pixel grayscale values of the interference region and the region fitting center are squared which results in the differences being further amplified, making the pixel grayscale value variance of the object region in the final segmentation result greater than the variance of the true river region. Thus, the within-cluster variance can not describe the differences of the pixel grayscale values inside the region accurately. Different from existing region-based models, Song et al. [22] presented a novel model based on cross entropy (CEACM), which utilizes the cross entropy to describe the differences between the initial image and the target image. Some desired segmentation results are obtained, whereas the over-segmentation still occurs in many cases. To address the above problem, a novel ACM for the segmentation of the remote sensing river images is presented. It utilizes the median of the pixel grayscale values inside each region as the region fitting center and further utilizes the median absolute deviation of the pixel grayscale values inside each region to describe the differences of the pixel grayscale values inside that region, which avoids the negative effects of the interference region to a great extent. Consequently, the presented model can segment the remote sensing river images accurately. Then, the fusion information of within-cluster variances and median absolute deviations of pixel grayscale values inside the object