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A skew Normal Mixture Model with Noise Estimation for image segmentation

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Abstract: Accurate image segmentation is an essential step in image processing. Gaussian mixture model (GMM) has been widely used for image segmentation due to its low complexity and high accuracy. However, the model assumes that the intensity distributions of images are symmetric, which makes it hard to obtain ideal results for images with asymmetric distributions. In addition, the model does not consider any noise, which makes it difficult to obtain ideal distribution fitting results when the image contains severe noises. Furthermore, the model only considers the distribution information without any spatial information, so it is sensitive to noise when segmenting images. To address these issues, we model noise with a Gaussian distribution and couple it into a skewed normal mixture model to reduce the effect of asymmetric distributions and noise and can obtain more accurate distribution fitting results. To further reduce the effect of noise, we propose a new anisotropic spatial information constraint term that preserves detailed information while reducing the effect of noise. Finally, an improved EM algorithm is proposed to solve the parameters of the model. Experimental results on synthetic and natural images show that our method achieves better segmentation results compared to other models.

Keywords: Skew normal distribution, Noise estimation, Anisotropic spatial information, Improved EM algorithm

1. Introduction

In most areas of digital image processing, image segmentation has a wide range of applications, such as industrial automation, production process control, online product inspection, image coding, document image processing, remote sensing and biomedical image analysis, security monitoring, as well as military, sports and other aspects. In the processing and analysis of medical images, image segmentation plays an effective role in guiding the three-dimensional display of diseased organs in people's bodies or in determining and analyzing the location of lesions; In the analysis and application of road traffic conditions, image segmentation technology can be used to separate the target vehicle to be extracted from the fuzzy and complex background such as monitoring or aerial photography; Remote sensing image segmentation is also widely used in military fields, such as strategic and tactical investigation, military marine mapping, etc. High-resolution remote sensing image segmentation data can be used for natural disaster monitoring and evaluation, map drawing and updating, forest resources and environment monitoring and management, agricultural product growth detection and yield estimation, urban and rural construction and planning, coastal area environmental monitoring The development of archaeological and tourism resources provides

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detailed ground information. The segmentation of target houses and roads plays an indispensable role in urban construction and land planning. In the process of transforming data into information, the segmentation of remote sensing images plays a very important role

The methods of image segmentation are to separate the image into non-overlapping regions with the same properties. Image segmentation is a very important and difficult problem in many fields such as image processing and understanding, pattern recognition and artificial intelligence. It is a key step in computer vision technology, so accurate image segmentation is particularly important.

At present, many image segmentation methods have been proposed1, mainly including threshold based image segmentation algorithm, clustering based image segmentation algorithm, finite mixture model(FMM) and deep learning based image segmentation algorithm, etc. The finite mixture model is widely used because of its simple algorithm and small sample demand. We mainly study image segmentation based on finite mixture model. Gaussian mixture model(GMM) is widely used in image segmentation because of its simple algorithm and fast running speed. However, it also has many problems, for example, it only applies to symmetric data and has no good results for asymmetric data; Only the distribution information is considered, and the spatial information is not considered, so a good segmentation result cannot be obtained for the data with serious noise.

As the algorithm is sensitive to noise, many people propose to integrate spatial information, that is, Markov into the algorithm. Markov process is a kind of stochastic process, which was proposed by Russian mathematician A.A. Markov in 1907. We have selected the algorithm that uses Markov to improve spatial information in recent years, as follows: SCDMM6, FRSCGMM13, SCAGMM9, SCGAGMM10 and SCGAEM12. These five algorithms have achieved good segmentation accuracy, but in order to better reduce the noise interference, we model the noise on the model, which can estimate the variance of various noises, not limited to Gaussian white noise.

In addition to noise modeling, we also improve the spatial information. We propose anisotropic spatial information, which makes the algorithm show isotropy in homogeneous regions and anisotropy in edge and intersection regions during segmentation. Inspired by these articles, we propose a skew normal mixture model with noise estimation and spatial information constraints for image segmentation.

Our method is to first model the noise, then introduce the anisotropic spatial information, then integrate the three ideas into our overall model, and finally use the improved EM algorithm to estimate the parameters. The experimental results show that our method has the best segmentation accuracy and robustness.

The rest of this paper is organized as follows. In the second section, in view of our inspiration from some articles, we provided the theoretical basis for the feasibility of our method, introduced how to construct noise, and proposed and coupled anisotropic spatial information. Finally, we gave how to use the improved EM algorithm to estimate parameters. In the third section, we present the experimental results and compare them with other five advanced methods. In the fourth section, we summarize.

2. Proposed method

2.1. Finite mixture model

Let $x_i, i = (1,2, \ldots, N)$ denote the target image, where x_i with dimension D is an observation at the i th pixel of the image. Let the neighborhood of the i th pixel be presented by ∂_i. Labels are denoted by $(\Omega_1, \Omega_2, \ldots, \Omega_k)$. The finite mixture model (FMM) assumes that each observation x_i is independent and its probability density function(pdf) is defined as: