During the past decades, many SAR image segmentation methods have been proposed. The classical SAR image segmentation methods include threshold methods [4], [15] and clustering algorithms [6]–[8]. These methods produce the segmentation results by simply using the pixel’s amplitude value and do not take into account the characteristics of the SAR images. Hence, the segmentation error is inevitable. Some feature extraction methods are also very popular in SAR image segmentation [9], [10]. These methods can produce promising results only if the feature extraction and feature selection are carefully designed.

在过去的几十年中，已经提出了许多SAR图像分割方法。 经典的SAR图像分割方法包括阈值方法[4]，[15]和聚类算法[6] – [8]。 这些方法仅使用像素的幅度值即可产生分割结果，而没有考虑SAR图像的特征。 因此，分割错误是不可避免的。 一些特征提取方法在SAR图像分割中也很流行[9]，[10]. 只有精心设计了特征提取和特征选择，这些方法才能产生有希望的结果。

To improve the segmentation performance, level-set methods [11], [12], Markov random field (MRF) methods [13]–[18], conditional random field methods [19]–[21], and multinomial latent model [22] are proposed for segmentation. These statistical model-based methods are getting increasing attention, which is because of their solid mathematical foundation and capability of utilizing the local spatial information during the segmentation process.

为了提高分割性能，使用水平集方法[11]，[12]，马尔可夫随机域（MRF）方法[13] – [18]，条件随机域方法[19] – [21]和多项式潜 提出了模型[22]用于分割。 这些基于统计模型的方法越来越受到关注，这是因为它们具有扎实的数学基础以及在分割过程中利用局部空间信息的能力。

Generally speaking, the statistical model-based methods mainly consist of the feature models and the spatial contextual models. The feature models reflect the statistical properties of amplitude or texture of the SAR images, and the spatial contextual models describe the local spatial relation-ships of the images. MRF model is typical in the statistical model-based methods [13]–[16]. Moreover, the classical MRF model is extended to the hierarchical MRF model, which incorporates the interactions between different scales of the image [14], [15]. This hierarchical scheme captures both the local and global information of the image, which improves the segmentation performance. The lately proposed multinomial latent model [22] achieves promising results, because it combines the amplitude and texture feature to describe the feature model. The multinomial logistic function is used to describe the spatial contextual model.

一般来说，基于统计模型的方法主要由特征模型和空间上下文模型组成。特征模型反映了SAR图像的幅度或纹理的统计属性，而空间上下文模型则描述了图像的局部空间关系。在基于统计模型的方法中，MRF模型是典型的[13] – [16]。此外，经典的MRF模型扩展到分层MRF模型，该模型合并了图像不同比例之间的相互作用[14]，[15]。这种分层方案可以捕获图像的本地和全局信息，从而提高了分割性能。最近提出的多项式潜在模型[22]取得了令人鼓舞的结果，因为它结合了幅度和纹理特征来描述特征模型。多项逻辑函数用于描述空间上下文模型。

In the spatial contextual model of the above methods, the relationships between the labels are captured by comparing the label of the central pixel and the labels of the surrounding pixels. It implies that the weights of the surrounding pixels to the central pixel are the same. However, this single spatial relationship is difficult to deal with the heterogeneous structures of the SAR images. For example, the weights of the surrounding pixels to the central pixel in the edge region are anisotropic. Unlike the edge region, the weights of the surrounding pixels to the central pixel in the homogeneous region are isotropic. The two spatial relationships are obviously different. Therefore, different structures should be considered in the neighborhood when the relationships between the central pixel and the surrounding pixels are described. A widely used solution for this issue is first to divide the image into regions with different characteristics and then apply suitable strategies to handle different regions [23]–[28]. In [23], the natural image was divided into structural domain and texture domain by the sketch graph. The sparse coding model and MRF model were used to represent the image intensities of the two domains for reconstruction.在上述方法的空间上下文模型中，通过比较中心像素的标签和周围像素的标签来捕获标签之间的关系。这意味着周围像素与中心像素的权重相同。但是，这种单一的空间关系很难处理SAR图像的异构结构。例如，边缘区域中的周围像素相对于中心像素的权重是各向异性的。与边缘区域不同，均匀区域中周围像素对中心像素的权重是各向同性的。两种空间关系明显不同。因此，当描述中心像素与周围像素之间的关系时，应该在附近考虑不同的结构。针对此问题的一种广泛使用的解决方案是，首先将图像分为具有不同特征的区域，然后应用适当的策略来处理不同的区域[23]-[28]。在[23]中，通过素描图将自然图像分为结构域和纹理域。稀疏编码模型和MRF模型用于表示两个域的图像强度进行重建。

Afterward, Shi et al. [24] divided the high-resolution panchromatic image into nonstructural and structural regions by sketch graph. Then, a learning interpolation method was used to fuse the high-resolution panchromatic image and the low-resolution multispectral image. Recently, Wu et al. [27] proposed the SAR sketching model, which produced the sketch map of the SAR image. They used SAR sketch map to divide the SAR image into structural and nonstructural regions. Different strategies were designed for searching the local maximal homogeneous to reduce the speckle noise. Based on the SAR sketch map, Liu et al. [28] proposed hierarchical semantic model for PolSAR image classification. The hierarchical semantic model divided the PolSAR image into subspaces with different characteristics. Then, corresponding methods were adopted for classification.

之后，Shi等。 [24]通过素描图将高分辨率全色图像划分为非结构和结构区域。然后，使用学习插值方法融合高分辨率全色图像和低分辨率多光谱图像。最近，吴等。 [27]提出了SAR草图模型，该模型产生了SAR图像的草图。他们使用SAR草图将SAR图像分为结构区域和非结构区域。设计了不同的策略来搜索局部最大同质性以减少斑点噪声。基于SAR草图，Liu等人。 [28]提出了用于PolSAR图像分类的分层语义模型。 分层语义模型将PolSAR图像划分为具有不同特征的子空间。 然后，采用相应的方法进行分类。