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# Segmentation of Three-dimensional Electron Tomographic Images

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## 1. INTRODUCTION

The intuitive understanding of the process of segmentation is that of a compartmentalization of the image into coherent regions and the extraction of independent objects. Perhaps the most sophisticated segmentation mechanism is human vision, which is capable of interpreting a large variety of groups, associating them into classes and compartments, as well as finding relationships among them. Computer-based image segmentation algorithms typically perform only a single task, which is coupled to a specific application. Humans use a large variety of different criteria to segment images, e.g. similarity, proximity, continuity and symmetry. In electron tomography, the observer usually searches for a known shape or multiply occurring shapes to guide his segmentation. The separation criteria used are the gray value and the contrast between the feature and the environment. In a general sense, the aim is to group pixels or voxels into subsets which correspond to meaningful regions or objects. When regarding pictures by eye, one has an intuitive sense for the boundaries of meaningful objects and regions. When using the computer, however, it is difficult to find quantitative criteria which define meaningful areas on the basis of pixel properties such as contours, brightness, color, texture, etc.

Segmentation algorithms incorporate edge detection and shape recovery, which are essential for many visualization tools. Independently of whether the technique is interactive, semi-automatic or fully automated, the separation of 2D or 3D images into several more coherent regions, the properties of which—as defined by intensity or texture—are roughly uniform, becomes indispensable as the image complexity grows. In electron microscopy, the feature of interest usually corresponds to pixels possessing different intensities compared with the background, at least locally, or those grouped into certain patterns. The goal is to locate these regions within the image and then perform segmentation.

The need for segmentation increases dramatically when the images go from two dimensions to three. Apart from the increased image complexity, which is intrinsic to an increase of the dimensionality, the comprehension of an image is much more difficult, due to the limited visualization capabilities. The perception of a certain object is significantly hampered because it might be covered, shadowed or obscured by noise and other surrounding objects. Through segmentation, the field of view can be cleared and simplified to allow for its interpretation. In this way, the segmentation can be exploited for the design of masks, allowing the interpretation to focus on different features of an object.

Image segmentation techniques can be classified into two broad families: contour-based and region-based approaches. Contour-based approaches, e.g. snakes, usually start with a first stage of edge detection, followed by a linking process with the aim of detecting a boundary. Region-based approaches, e.g. segmentation with eigenvectors, to be discussed later, try to find partitions of the image pixels into sets with similar image properties.