Abstract

When performing morphological measurements of biological structural objects using an electron microscope, it is necessary to accurately identify the objects on the image. However, especially in ultra-thin section electron microscope images, the contours of objects are often unclear. For this reason, a great deal of time and effort is required for such segmentation. In this doctoral paper, as a solution to this problem, a new contour extraction method is proposed, which can semi-automatically extract contours on electron microscope images while reducing manual work as much as possible. This method is expected to be effective in creating training data for AI and in an immediate image analysis.

This method utilizes the properties of Gabor wavelets, which respond strongly to local contour images with specific orientation and frequency components. In order to extract contours more efficiently, the method newly devised to confine the Gabor wavelets in a limited rectangular image area. However, when using this method, the theoretical formula of the conventional Gabor wavelets cannot be used as it is, so a part of the theoretical formula has been improved. Using this improved Gabor wavelets, the coordinates and tangent angles of the contour points could be obtained. These pieces of information provide predictions of the neighboring contour points, and by repeating this method, an automatic contour tracking has been possible. However, it is necessary to appropriately set optimal parameters of Gabor wavelets according to the local image. Therefore, in this method, the results of automatic contour tracking are monitored one by one, and the optimum parameters are automatically reset when it is determined that the tracking has deviated. If the deviation still cannot be prevented, it is corrected with manual assistance. In this research, we newly developed a GUI tool to efficiently perform this assistant work.

Before applying the proposed method to electron microscope images, three kinds of model contour images were created to imitate the target contours, and the method was simulated using these images. The results showed that the method could extract contours without errors for clear contours, and also accurately extracted boundaries composed of similar patterns. Furthermore, it is noteworthy that even if the contours and boundaries were made unclear by blurring or noise in which the level of those were changed intentionally, the contours could be extracted within a certain tolerance range of error. Based on these results, the method was applied to cell organelles in yeast ultrathin section electron microscopy images. As a result, the contours of cell membrane, vacuole, nucleus, lipid and mitochondria were extracted with high accuracy, not only in the case of clear contrasts, but also for unclear contours that were difficult to determine even with the human eye. Notably, the contour of vacuolar membranes, which showed very complex morphology, was successfully extracted with little manual work. The method is expected to be useful for contour extraction in various fields not covered in this paper in the future.