LABORATORY OF BIOLOGICAL DIVERSITY

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Image processing methods significantly contribute to visualization of biomedical targets acquired from a variety of imaging techniques, including: wide-field optical and electron microscopy, X-ray computed tomography, magnetic resonance imaging and mammography. Quantitative interpretation of the deluge of complicated biomedical images, however, poses many research challenges. We have developed new computational methods based on mathematical morphology for quantitative image analysis. One of the most important purposes of image processing is to derive meaningful information, which is expressed as structural properties in images. Mathematical morphology is a nonlinear image processing method based on the set theory and is useful for the extraction of structural properties from an image. It can be used as a fundamental tool to analyze biomedical images.

I. Novel image processing method based on mathematical morphology

Image processing is a crucial step in the quantification of biomedical structures from images. As such, it is fundamental to a wide range of biomedical imaging fields. Image processing derives structural features, which are then numerically quantified by image analysis. Contrast enhancement plays an important role in image processing; it enhances structural features that are barely detectable to the human eye and allows automatic extraction of those features. To effectively recognize a region of interest, specific target structures must be enhanced while surrounding objects remain unmodified. A contrast enhancement technique which uses mathematical morphology enables selective enhancement of target structures. Based on set theory, mathematical morphology applies shape information to image processing.

Mathematical morphology operates by a series of morphological operations, which use small images called structuring elements (typically, a single structuring element is used). The structuring element acts as a moving probe that samples each pixel of the image. Since the structuring element moves in a fixed direction across the image, some intricate images (in particular, those whose structural details contain a variety of directional characters) may not be properly processed. Consequently, an artifact in the shape of structuring elements may be generated at the object periphery. Since objects in biomedical images consist of delicate structural features, this drawback is an especially serious problem.

To overcome this problem, we have proposed an extension of conventional mathematical morphology called rotational morphological processing (RMP). RMP based morphological filters have been applied to a wide variety of biomedical images, including electron micrographs, light micrographs and medical images such as mammographic images and chest X-ray images.

In this study, we have developed a novel RMP-based contrast enhancement method. The goal of the study is to enable enhancement of fine morphological features of a mass lesion with high suppression of surrounding tissues, such as mammary glands. The method uses a top-hat contrast operator, a well-known and commonly used morphological operation for extracting local features from a low-contrast image. The proposed method involves three steps: (1) selective extraction of target features by mathematical morphology, (2) enhancement of the extracted features by two contrast modification techniques and (3) segmentation of the target region (mass lesion) by using an automatic thresholding technique. The effectiveness of the method was quantitatively evaluated by the contrast improvement ratio (CIR) and its usefulness was demonstrated by applying it to various types of medical images. The results prove that the proposed method enables specific extraction and enhancement of mass lesions, which is essential for clinical diagnosis based on medical image analysis. Figure 1 shows a mammographic image enhanced by the proposed method.

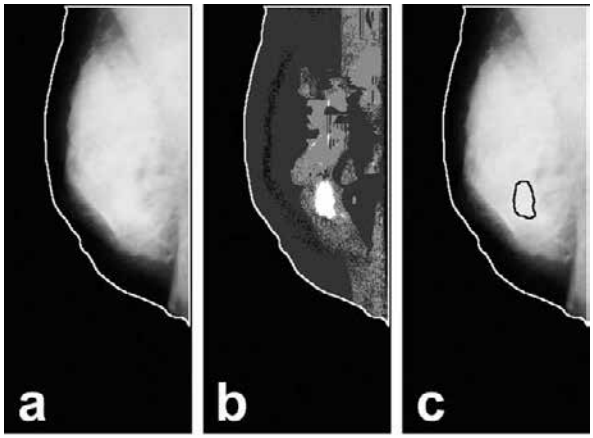

Figure 1. Image enhancement and target detection achieved by the proposed method for a mass lesion in a mammographic image. The images were obtained from the Mammographic Image Analysis Society (MIAS) database. (a) Original mammographic image (mdb179). (b) Enhancement result of candidates of mass lesion obtained by the proposed method. (c) Detection result of the lesion region.