Doctoral Thesis Abstract

Segmentation and Three-Dimensional Visualization of Pathological Changes in Mammary Gland in Ultrasound Images using Artificial Intelligence Methods

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This Ph.D. thesis addresses the use of artificial intelligence methods for segmenting breast tumors in two-dimensional ultrasound images (US) and the visualization of the three-dimensional model obtained in the volume reconstruction process. The data come from the image navigation system, providing the spatial orientation of ultrasound images. The study uses both clinical images and data recorded for laboratory experiments.

The research covered several stages. The first stage was designing a US image processing path to segment breast tumors. A modification of the fuzzy connectedness method was proposed for creating pseudo-color hybrid images. These images were subjected to semantic segmentation using a convolutional neural network, with its outcome being an initial contour in the active contour evolution. The settings and parameters of the methods were investigated in detail to optimize segmentation quality and processing time. The analysis involved a 5-fold cross-validation over a set of 993 images with different types of tumors from three independent public databases. The Dice coefficient was used to measure the segmentation quality, with a median of 0.86 obtained for the complete segmentation framework.

The second stage was developing a three-dimensional volume reconstruction method based on segmented 2D images and the corresponding transformation matrices from the image navigation system. The proposed approach of frame-acquisition-time-dependent reconstruction was tested using laboratory data simulating objects moving during scanning. The construction of a phantom to assess the accuracy of the reconstruction was the essential element of the experiment.

The third stage was to design an interactive application for visualizing the model based on parameters selected by the user to increase the potential usefulness of the proposed methodology in clinical practice. Visualization was possible in a canonical three-dimensional or registration-time-dependent two-dimensional setup. The application was tested on data from a simulation of a clinical study using a biopsy phantom.

The experiments and results show that image navigation during the ultrasound examination enables segmentation and spatial orientation of a 3D model of a neoplastic lesion based on 2D B-type US images, which was the goal of the study.

Keywords: computer-aided diagnosis, breast tumor, ultrasound, image segmentation, image navigation, 3D reconstruction, artificial intelligence, convolutional neural networks