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Segmentation of cancerous regions in liver using an edge-based and phase congruent region enhancement method ☆

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ABSTRACT

Segmenting low-contrast cancerous regions from Computed Tomography (CT) images is an important task. Region and edge-based active contours fail to perform with such images. Thus, edge-based phase congruent region enhancement is proposed for detecting low-contrast boundaries using new stopping function. The stages of the proposed method are: region separation, region enhancement and Distance Regularised Level Set Evolution (DRLSE) with new stopping function. First, cancerous region is delineated by creating phase map and converting it into an edge map by thresholding. Second, the feature map is created by enhancing features at the boundaries of edge map. The feature map is combined with original image to generate final image. Finally, stopping function is constructed for DRLSE based on the gradient of final image. Experiments were performed on 20 two dimensional and 4 three dimensional CT scans. The proposed method was compared with two active contours. Results prove the superiority of proposed method.

1. Introduction

Cancer is one of the most lethal non-communicable diseases and contributes to 13% of total deaths worldwide [1]. It is curable if detected early and accurately. In addition, in the prognosis and diagnosis of cancer, it is necessary to know beforehand the size and area of spread of the cancer. In this regard, studies related to medical imaging play an important role in the early diagnosis of cancer. Medical imaging has emerged as a non-invasive tool for diagnosis of diseases. Many medical modalities related to imaging are used, such as X-rays, Ultrasound, Computed Tomography (CT) scanning and Magnetic Resonance Imaging (MRI). As the volume of digital imaging data is massively increasing, it is not possible for radiologists to diagnose diseases manually, and this may lead to misdiagnosis. Thus, computer-aided diagnosis systems have attracted a great deal of interest for the diagnosis of diseases as a method to improve the diagnosis accuracy and efficiency of radiologists [2]. The most important part of a computer-aided diagnosis system is image segmentation.

Image segmentation is the process of dividing an image into multiple regions. The segmented region is also known as the Region of Interest (ROI). These ROIs are used as informative inputs for image processing techniques, e.g., feature extraction, selection and, ultimately, classification of diseases. Thus, effective image segmentation is of utmost importance in medical image processing. In this paper, our main focus is on the segmentation of CT images of abdomen having an image of cancer

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with low contrast and weak boundaries (Fig. 1). An efficient and accurate image segmentation method is not only helpful in detecting the location of cancer in the liver but is equally important for determining the extent by which cancer has spread across the liver. In addition, it also provides information about the extent of damage to nearby organs or the liver. If image segmentation provides incorrect information about the extent of cancer by failing to detect the desired boundaries of the ROI, then a Computer-Aided Diagnostic (CAD) system may provide a false diagnostic report. Thus, segmentation methods need to be sensitive enough to detect the desired boundaries and area of cancer spread so that an accurate diagnosis can be achieved. Extensive studies have been performed in the past on medical image segmentation, and many methods have been proposed for the same. Sharma and Aggrawal [3] reviewed various methods of medical image segmentation and discussed the merits and demerits of segmentation methods. Ahmed et al. [4] surveyed semiautomatic and automatic medical image segmentation methods. Sridhar et al. [5] segmented abnormal masses from mammogram images using combination of watershed transform and Markov random fields. Linguraru et al. [6] used shape and physiological features along with probabilistic location information for segmenting the liver and analysed the proportion of the tumour in the liver. Hame and Pollari [7] proposed semi-automatic liver tumour segmentation method based on non-parametric intensity distribution estimation and hidden Markov model and attained high accuracy in segmenting desired ROI. Fang et al. [8] addressed the problem of low contrast boundaries and proposed new segmentation method based on optimal tree-metrics graph cuts on multi-phase contrast enhanced MRI images. Zhang et al. [9] proved that non-intensity based edge detection and subtraction method is an effective tool in segmentation of tumourous tissues in liver. Zhou et al. [10] presented a performance benchmarking study on liver tumour segmentation using region growing with knowledge-based constraints.

The deformable contour is one of the most reliable and extensively used techniques in medical image segmentation. The reason is its ability to handle complex structures [11]. Evgin et al. [12] proposed fully automated variational level set approach for liver segmentation. The evolution and termination of contour is controlled by region and edge bases special pressure force, thus does not rely on distance regularization term and conventional edge stopping functions [12]. The method is applied on ten data sets and results indicated that proposed method can accurately and efficiently segment liver images [12]. Linguraru et al. [13] used shape correction methods in geodesic active contours for accurate segmentation of tumour and liver. Patil et al. [14] designed semiautomatic segmentation method that employed multiple levels of thresholding for segmentation of tumour from liver. Smeets et al. [15] used semiautomatic level set technique for segmentation of liver tumours in CT images in which the statistical pixel classification algorithm is used for the evolution of level sets. Kadoury et al. [16] proposed method for liver tumour segmentation in which higher-order potentials ensure regional consistency. Peng et al. [17] presented semiautomatic level set based liver segmentation method that uses region and edge information for evolution. Results indicate that integrating region and edge information leads to the superior performance in delineating ambiguous liver edges.

Deformable contours, referred to as snakes, are used for detection of nearby edges. These snakes were represented by parametric curves, Lagrangian formulation and based on the principle of energy minimisation for the detection of nearby edges. Ersoy et al. [18] proposed edge guided level sets for analysis of spreading of cells. Evgin [19] in his thesis presented overview of liver segmentation methods and proposed level set method in which the evolution of contour using special signed pressure function based edge indicator is done without using any regularized term. Yang et al. [20] presented hybrid semiautomatic method that consists of fast marching and thresholding based level set approach for segmentation of liver from abdominal CT image. Li et al. [21] applied level set for segmentation of liver tumour in Two Dimensional (2D) and Three Dimensional (3D) CT images. Such contours use Euler formulation, and the evolution of contours is performed using the level set method.

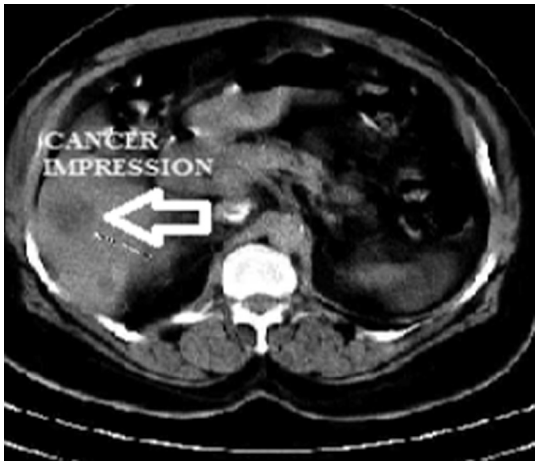

Fig. 1. CT image with cancer displaying weak boundaries (intensity of infected and non-infected tissues is almost the same).

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