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Original Research Article

Multi-modal framework for automatic detection of diagnostically important regions in nonalcoholic fatty liver ultrasonic images

R. Bharath [a,*], P. Rajalakshmi [a], Mohammad Abdul Mateen [b]

[a] WiNet Research Lab, Department of Electrical Engineering, Indian Institute of Technology Hyderabad, Kandi, Sangareddy 502285, Telangana, India
[b] Asian Institute of Gastroenterology, Hyderabad 500082, Telangana, India

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ABSTRACT

The severity of fat in ultrasonic liver images is quantified based on characteristics of three regions in the image namely diaphragm, periportal veins and texture of liver parenchyma. The characteristics of these regions vary with the severity of fat in the liver, and is subjected to low signal to noise ratio, low contrast, poorly defined organ boundaries, etc., hence locating these regions in ultrasound images is challenging task for the sonographers. Automated detection of these regions will help the sonographers to do accurate diagnosis in shorter time, and also acts as a fundamental step to develop automated diagnostic algorithms. In this paper, we propose a novel multi-modal framework for detecting diaphragm, periportal veins and texture of liver parenchyma in ultrasonic liver ultrasound images. Since the characteristics of these regions differ from each other, we propose a specific algorithm for detecting each region. Diaphragm and periportal veins are detected with the combination of Viola Jones and GIST descriptor based classifier, while homogeneous texture regions are detected with the combination of histogram features based classifier and connected components algorithm. The proposed algorithm when tested on 180 ultrasound liver images, detected the diaphragm, periportal veins and texture regions with an accuracy of 97%, 91% and 100% respectively.

1. Introduction

Nonalcoholic fatty liver disease (NAFLD) is one of the leading cause for the dysfunction of the liver and prevalent in 30% of general population in the developed countries [1]. If NAFLD is untreated, it may progress into chronic liver diseases such as fibrosis, cirrhosis, hepatocellular carcinoma, liver cancer, etc. [2,3]. Depending on the severity of fat, the liver is categorized

* *Corresponding author at*: WiNet Research Lab, Department of Electrical Engineering, Indian Institute of Technology Hyderabad, Kandi, Sangareddy 502285, Telangana, India.
E-mail addresses: ee13p0007@iith.ac.in (R. Bharath), raji@iith.ac.in (P. Rajalakshmi), drmateen@gmail.com (M.A. Mateen).
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into Normal, Grade I, Grade II and Grade III respectively. If the density of fat is less than 5% it is considered as Normal, 5–33% as Grade I, 33–66% as Grade II and greater than 66% as Grade III respectively [4]. The severity of fat in the liver is determined using invasive and noninvasive procedures. Invasive procedures which include blood tests and biopsies are associated with complications like bleeding, bile leakage and infections. Hence doctors recommend for noninvasive procedures like magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound scanning [5,6]. MRI and CT being expensive, doctors prefer for ultrasound scanning which has the advantages of real-time imaging, safety and less expensive [7,8]. Although the ultrasound scanning is widely used, the diagnostic accuracy in quantifying the fat in the liver is very low due to the subjectivity involved in the scanning. Strauss et al. found that there is a low mean inter and intra-observability of 72% and 76% respectively in discriminating between normal and fatty liver, while inter and intra-observability of 47–59% and 59–64% respectively is observed in discriminating the severity of fat within Grade I, Grade II and Grade III classes. It is also found that 32–34% of fatty liver images belong to Grade I and Grade II are not distinguishable to sonographers eye [9]. Therefore there is a need for computer-aided diagnosis (CAD) algorithms to assist the sonographers to accurately diagnose the fatty liver diseases.

In literature [6,10–19], authors are mainly focused on developing CAD algorithms for discriminating normal liver with fatty liver images, where fatty liver constituted liver images ranging from Grade I to Grade III category, while further distinction within the fatty liver grades is not extensively studied [20]. Accurate quantification of fat in the liver carries paramount importance in liver diagnosis, for example in liver transplantation, even a Grade I fatty liver of donor can increase the potentiality of liver failure in the recipient and also there is a high probability that the donor will get diseased [6,21]. The patients who undergo liver resections with Grade III fatty liver are expected likely to suffer from post-operative complications [22]. Therefore accurate quantification of fat in the liver will prevent the patients to suffer from chronic diseases and complications associated with NAFLD. In [20,23–28], the authors proposed CAD algorithms for quantifying the fatty content in the liver. In all these algorithms, authors employed manual cropping for detecting the region of interest (RoI). RoI includes the homogeneous texture of liver parenchyma, pixels along the direction of wave propagation, etc. To avoid manual intervention in CAD, researchers proposed algorithms which works on complete images [17,29–32]. While dealing with entire image, we are extracting the features from the regions which is neither important nor convey information useful for diagnosis leading to ineffective feature representation. Hence, in developing CAD algorithms, we have to ensure that the features are extracted only from diagnostically important regions. Detecting RoI's in ultrasonic liver images is challenging due to

- Low signal to noise ratio, poorly defined organ boundaries, low contrast, artifacts caused due to acoustic shadows, etc.
- Variation in the characteristics of the RoI within intraclass and interclass images.

In this paper, we propose an algorithm for automated detection of the RoI's useful for quantifying the fat in liver ultrasound images. The quantification of fat in the liver through ultrasound scanning is done by perceiving characteristics in three regions of the liver such as diaphragm, periportal veins and texture of liver parenchyma. The RoI's of the diaphragm, periportal veins and texture of liver parenchyma of the liver ultrasound image is shown in Fig. 1. The characteristics of these region vary accordingly with the severity of fat present in the liver. The characteristics of these RoI's with respect to different grades of fatty liver is discussed in Table 1 [20,33]. Based on the characteristics of RoI's, the sonographers quantify the fat in the liver. Automatic detection of these regions will assist sonographers to make an accurate diagnosis in short time and also serves as a fundamental step for the development of robust automated diagnostic algorithms for quantification of fat in the liver.

In this paper, we propose an automatic algorithm for detection of diaphragm, periportal veins and homogeneous texture regions of liver parenchyma. Since each RoI is different with respect to other RoI's, we developed a specific algorithm for detecting each RoI. The novelties of the paper are:

- For detecting RoI of a diaphragm, we propose an algorithm which is a combination of Viola Jones (VJ) algorithm [34], GIST descriptor [35] based cubic SVM classifier and active contour segmentation [36,37]. The VJ algorithm and GIST

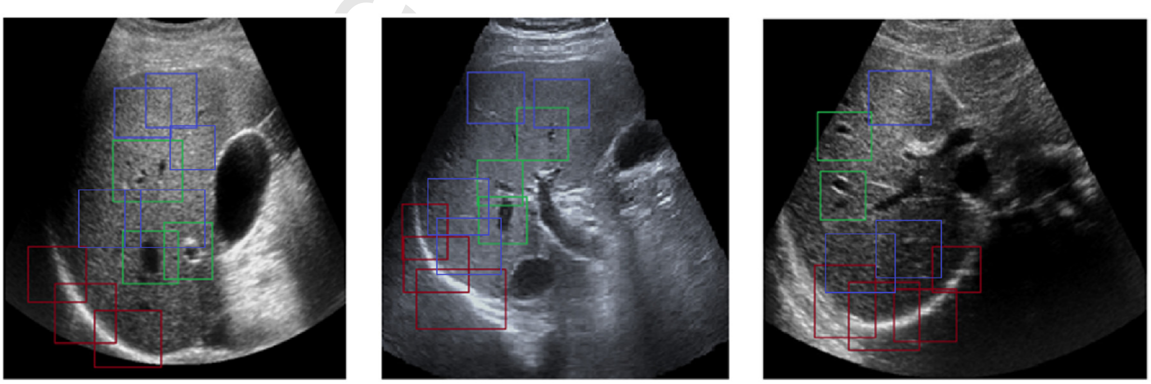

Fig. 1 – Ultrasonic liver images. Red boxes indicates the diaphragm, green boxes indicates periportal veins and blue boxes indicates RoI corresponding to homogeneous texture. (For interpretation of the references to color in this legend, the reader is referred to the web version of the article.)

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