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Original Research Article

Automated quantification of ultrasonic fatty liver texture based on curvelet transform and SVD

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ABSTRACT

Fatty liver is a prevalent disease and is the major cause for the dysfunction of the liver. If fatty liver is untreated, it may progress into chronic diseases like cirrhosis, hepatocellular carcinoma, liver cancer, etc. Early and accurate detection of fatty liver is crucial to prevent the fatty liver progressing into chronic diseases. Based on the severity of fat, the liver is categorized into four classes, namely Normal, Grade I, Grade II and Grade III respectively. Ultrasound scanning is the widely used imaging modality for diagnosing the fatty liver. The ultrasonic texture of liver parenchyma is specific to the severity of fat present in the liver and hence we formulated the quantification of fatty liver as a texture discrimination problem. In this paper, we propose a novel algorithm to discriminate the texture of fatty liver based on curvelet transform and SVD. Initially, the texture image is decomposed into sub-band images with curvelet transform enhancing gradients and curves in the texture, then an absolute mean of the singular values are extracted from each curvelet decomposed image, and used it as a feature representation for the texture. Finally, a cubic SVM classifier is used to classify the texture based on the extracted features. Tested on a database of 1000 image textures with 250 image textures belonging to each class, the proposed algorithm gave an accuracy of 96.9% in classifying the four grades of fat in the liver.

1. Introduction

Accumulation of excess fat in liver cells termed as Nonalcoholic Fatty Liver Disease (NAFLD) is an abnormal condition of a liver etiologically associated with hepatic manifestation of metabolic syndrome, specifically insulin resistance. NAFLD is associated with obesity, type 2 diabetes, hyperlipidemia, side effects of certain medications, cardiovascular diseases, etc. NAFLD is one of the leading causes of liver dysfunction and is rapidly growing health problem in the world. It is estimated that up to 30% of general population in the developed countries are prevalence with NAFLD [1]. NAFLD is observed in 80–90% of obese patients, 30–50% of diabetic patients and

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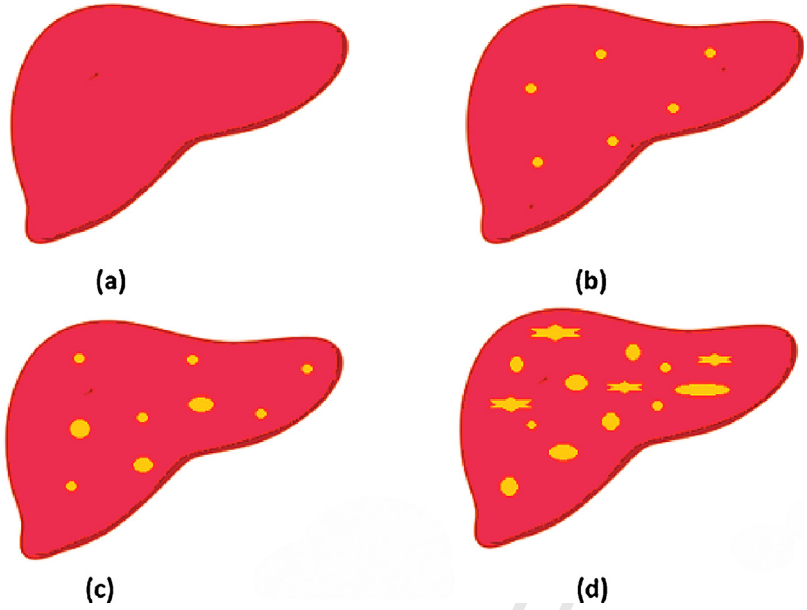

Fig. 1 – Graphical representation of NAFLD, yellow patches indicates the fat or triglycerides (a) Normal, (b) Grade I, (c) Grade II, and (d) Grade III fatty liver.

90% of hyperlipidemia patients [2]. If the underline problem associated with NAFLD is not detected nor treated, the NAFLD can progress into chronic liver diseases.

From recent investigations, it is found that 50% of patients with NAFLD has progressed to liver fibrosis, 15% of patients with NAFLD has progressed into liver cirrhosis, while 3% of patients with NAFLD has lead to liver failure resulting in liver transplantation [3]. Hence, early detection of fatty liver becomes crucial in preventing the liver progressing into chronic liver diseases.

The severity of the NAFLD is characterized by the density of fatty granules accumulated in the tissues of a liver [4]. The visual representation regarding the presence of fatty granules corresponding to different grades of the nonalcoholic fatty liver is shown in Fig. 1.

Brunt et al. categorized NAFLD into simple steatosis (Normal or Grade 0) and nonalcoholic steatohepatitis (NASH). NASH is further categorized into Grade I, Grade II and Grade III, as shown in Table 1 [4]. If the concentration of fat in the liver is less than 5%, then the liver is considered as Grade 0 which is treated as a Normal condition. If the concentration of fat in the liver is in between 5 and 33%, then the liver is considered to be in Grade I condition. Higher concentration of fatty levels in liver such as 33–66% is considered as Grade II, and greater than 66% is considered as Grade III respectively. In general, Grade 0 and Grade I does not affect the functionality of the liver and does not require medication. Grade II and Grade III conditions affect the functionality of the liver and patients need medical attention to prevent the liver progressing into chronic diseases.

Table 1 – Grading and condition of NAFLD based on the percentage of fat present in the liver.

NAFLD	Degree of steotosis	Grading	Condition
Simple Steotosis	< 5%	Grade 0	Normal
NASH	5–33%	Grade I	Mild
	33–66%	Grade II	Moderate
	>66%	Grade III	Severe

Fatty liver is diagnosed using invasive and noninvasive procedures; invasive procedures include biopsies, blood tests, etc., while noninvasive procedures includes imaging techniques like ultrasound scanning, Magnetic Resonance Imaging (MRI) and Computed Tomography (CT). Invasive procedures are painful, and it is associated with complications like infections, bleeding, bile leakage, etc. Hence, doctors recommend for noninvasive imaging procedures. Ultrasound scanning is widely used imaging modality for diagnosing the fatty liver since it offers real-time, safer and economical compared to MRI and CT. Unlike, MRI and CT (where images are captured automatically by systems without manual intervention), the ultrasound scanning is performed by humans resulting in high subjectivity. The subjectivity depends on parameters like the skill of a sonographer, age, gender, body mass index of a patient, etc. Specific to the quantification of fat in liver through ultrasound scanning, Strauss et al. [5] reported that there is a mean interobserver and intraobserver agreement of 72% and 76% respectively in detecting the normal liver from the fatty livers, while in quantifying the severity of fat there is a mean interobserver and intraobserver agreement of 47–59% and 59–64% respectively. Computer aided diagnostic algorithms can nullify the bias caused due to the subjectivity thus helping sonographers to take confidence decisions.

The texture of liver in ultrasound image appears specific to the concentration of fat present in the liver [6–8]. Sonographers quantize the fatty content of the liver based on the texture structural and perceptual properties of a liver; these include