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Decision support system for fatty liver disease using GIST descriptors extracted from ultrasound images

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A B S T R A C T

Steatosis or fatty liver disease (FLD) is characterized by the abnormal retention of large vacuoles of neutral fat in the liver cells, either due to alcoholism or metabolic syndrome. Succession of FLD can lead to severe liver diseases such as hepatocellular carcinoma, cirrhosis and hepatic inflammation but it is a reversible disease if diagnosed early. Thus, computer-aided diagnostic tools play a very important role in the automated diagnosis of FLD. This paper focuses on the detection of steatosis and classification of steatotic livers from the normal using ultrasound images. The significant information from the image is extracted using GIST descriptor models. Marginal Fisher Analysis (MFA) integrated with Wilcoxon signed-rank test helps to eliminate the trivial features and provides the distinctive features for qualitative classification. Finally the clinically significant features are fused using classifiers such as decision tree (DT), support vector machine (SVM), adaBoost, *k*-nearest neighbor (*k*NN), probabilistic neural network (PNN), naïve Bayes (NB), fuzzy Sugeno (FS), linear and quadratic discriminant analysis classification of normal and abnormal liver images. Results portray that PNN classifier can diagnose FLD with an average classification accuracy of 98%, 96% sensitivity, 100% specificity and Area Under Curve (AUC) of 0.9674 correctly.

1. Introduction

Accretion of triglyceride fat in the hepatocytes is called fatty liver and it results in Fatty Liver Disease (FLD) or steatosis when the fat deposition on the liver exceeds 10% or more than its total weight [1]. Fatty liver is universally linked to chronic alcoholism, metabolic disorders, inflammatory bowel disease, drugs and toxins [2]. Alcoholic fatty liver disease (AFLD) and non-alcoholic fatty liver disease (NAFLD) are two categories of FLD caused either due to excessive alcohol consumption or excessive fat deposition [3]. Accumulation of undue fat may lead to hepatic inflammation, cirrhosis, steatohepatitis and hepatocellular carcinoma irrespective of its type [4].

According to the recent statistics, 25 million US citizens are affected by liver or biliary disease and out of these, approximately 50% population have no symptoms. In United Kingdom, around 25% deaths from liver disease are due to excessive alcohol consumption [5]. Rising rate of obesity is the major cause factor of NAFLD and it is reported that by 2050, the incidence rate of NAFLD would rise by 50% [6].

Steatosis or fatty liver disease (FLD) is a common liver disorder and is curable if diagnosed early. Physical examination, blood tests, liver biopsy, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound are some of the diagnostic tests in the assessment of FLD. Physical examination and blood test may not lead to efficient analysis. Liver biopsy is the standard estimation tool in steatosis but it is hardly preferred for being an invasive technique and is prone to sampling errors. Non-invasive techniques such as CT and MRI are insensitive in identifying steatosis of less than 25–30% [7]. Ultrasound has a higher sensitivity than CT, around 82–94% and specificity higher than 82% but it has poor visualization in obese patients

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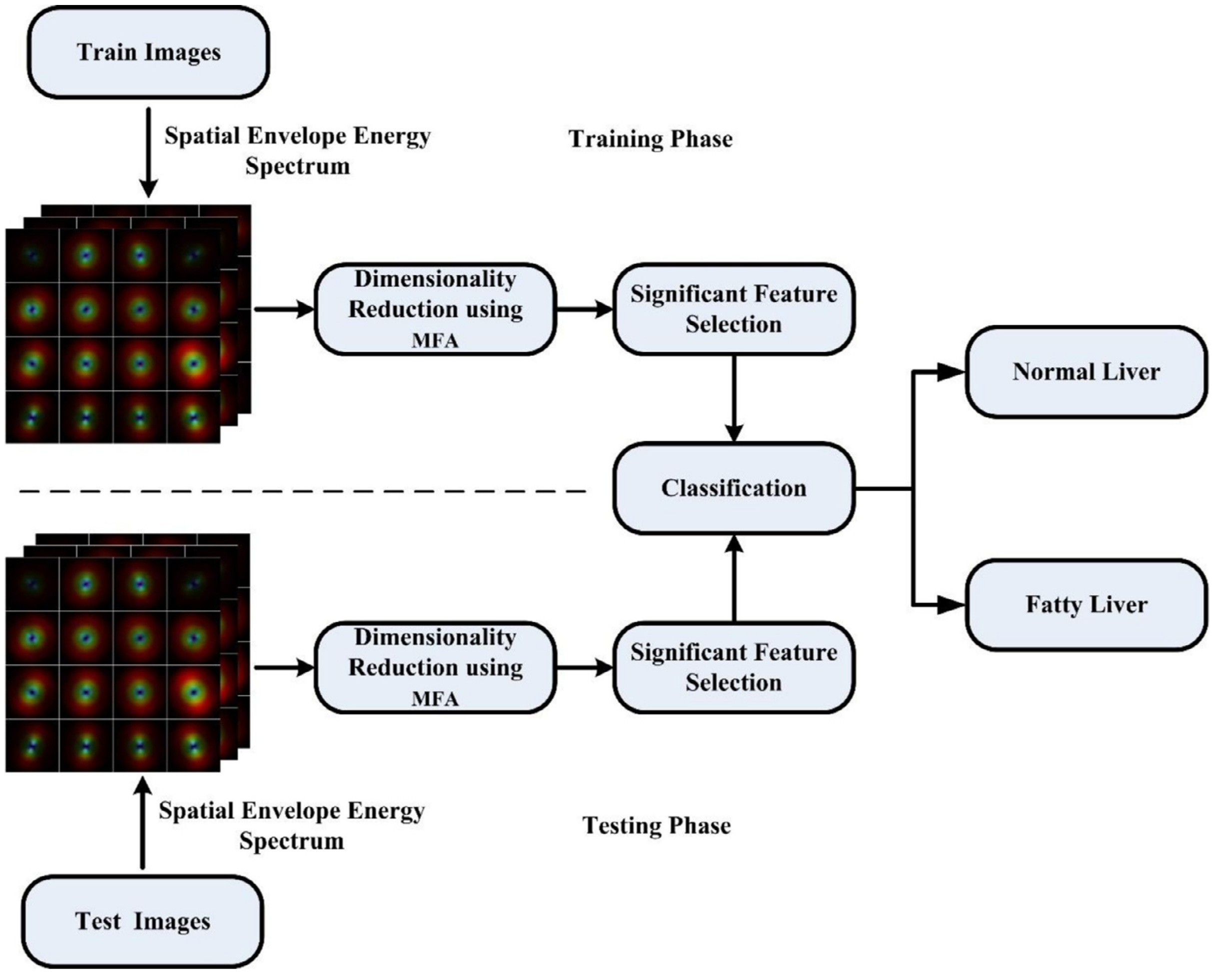

Fig. 1. Block diagram showing the proposed technique.

and is less specific. Irrespective of these disadvantages, ultrasound is commonly preferred in the identification and monitoring of FLD due to its extensive accessibility in the current medical environment [8].

Computer-aided diagnostic (CAD) techniques can be implemented for the efficient diagnosis of FLD using ultrasound images of a liver as it reduces the inter-observer variability and increases the ultrasound specificity. Ultrasound images of normal and abnormal liver are processed to extract discriminative and momentous features. Dimensionality reduction analysis is performed to reduce innumerable features and characteristic features are selected using ranking methods. Supervised and unsupervised classifiers are trained using these significant features for effective classification of normal and abnormal liver images [9]. One of the latest studies by Acharya et al. [10] describes a CAD system called Symtosis, developed using texture energy, wavelet transform and higher order spectra features extracted from normal and FLD affected liver images. Learning based classifiers such as DT, fuzzy Sugeno are used for the classification of normal and abnormal livers. These CAD techniques have been used for the other medical applications like detection of diabetes retinopathy [55], coronary artery disease [56], sudden cardiac death [57] and epilepsy [58].

This work proposes an efficient diagnosis of fatty liver disease using ultrasound liver images of normal and abnormal livers. Fig. 1 describes the proposed method with a detailed block diagram. Ultrasound liver images are divided into training and testing images for building a robust classifier and thus, its performance is estimated. The GIST descriptors are applied to the images, representing them in a *spatial envelope energy spectrum*. Immeasurable features are extracted from the spatial envelope energy spectrum and are analyzed using Marginal Fisher Analysis (MFA). MFA is a dimensionality reduction technique that reduces the number of extracted features and Wilcoxon signed-rank test selects the best discriminating features. Selected feature values and the typical ultrasound images of normal or steatotic as concluded by radiologists are used to train different classifiers. After training, the significant test features are fused into different classifiers such as decision tree (DT), linear and quadratic discriminant analysis (LDA and QDA), *k*-nearest neighbor (*k*NN), fuzzy Sugeno (FS), probabilistic neural network (PNN), naive Bayes classifier (NBC) and support vector machine (SVM), adaBoost, to evaluate the performance of a classifier and obtain the best classification results.

This manuscript is divided into six different sections including Introduction in Section 1. Section 2 gives the details on ultrasound data acquisition and techniques used in the feature extraction and selection. Section 3 briefly describes all the classifiers followed by results in Section 4. Section 5 summarizes the previous studies on FLD with conclusion in Section 6.

2. Materials and methods

This section provides an explanation of ultrasound liver images, briefly describes the techniques employed for feature extraction, dimensionality reduction and feature selection to obtain characteristic and distinguishing features.