Liver Tumor Detection by Classification through FD Enhancement of CT Image

N. Ghatwary, A. Ahmed, H. Jalab

***Abstract*—**In this paper, an approach for the liver tumor detection in computed tomography (CT) images is represented. The detection process is based on classifying the features of target liver cell to either tumor or non-tumor. Fractional differential (FD) is applied for enhancement of Liver CT images, with the aim of enhancing texture and edge features. Later on, a fusion method is applied to merge between the various enhanced images and produce a variety of feature improvement, which will increase the accuracy of classification. Each image is divided into NxN non-overlapping blocks, to extract the desired features. Support vector machines (SVM) classifier is trained later on a supplied dataset different from the tested one. Finally, the block cells are identified whether they are classified as tumor or not. Our approach is validated on a group of patients' CT liver tumor datasets. The experiment results demonstrated the efficiency of detection in the proposed technique.

***Keywords*—**Fractional differential (FD), Computed Tomography (CT), fusion.

I. Introduction

THROUGHOUT the last decade, liver malignant tumor patients' were at high risk, due to rapid case deterioration leading to death [1]. Detection at early stage tumors is considered of high prominence for early diagnosis, treatment, and medical plan. Image analysis is considered an efficient methodology by analyzing feature such as texture analysis, boundaries, shape, and contrast [2]. Manually detecting tumor based on their location or shape information is an irritating process since tumors vary through the slices of a patient's CT scans and differs from one patient to another [3]. Therefore, the key point for detection is how to enhance the features to emphasize/distinguish tumor/non-tumor regions to be able to detect the occurrence of a tumor.

Enhancement is the process of improving the image details by tuning particular parameters/features [4]. It makes feature classification easier, as after the enhancement an improved discrimination would appear. Fractional Differential (FD) mechanism which is a branch from Fractional Calculus aimed at enhancing the image features.

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Fractional Calculus is a field of mathematics that provides derivation and integration of functions to non-integer order [5]. Operators with non-integer order were validated to be able to describe the behavior of materials over massive frequency and time scale. In image processing, the gray-level value between neighboring pixels often expressed by the complex texture detail features [5]. Different works were proposed in literature to enhance grey images using FD, but medical images have different features than normal ones due to the contents inside a medical image such as bones, tissues, glands, organs, etc…having various properties, in addition to the exposure of radiation from the machines.

In our proposed model, a new fusion between various FD enhanced medical images is investigated to enhance the image properties and differentiate the normal tissues from tissues with lesions (tumors). Moreover, we provide quantitative evaluation of the effect of FD enhancement on the detection by classification, as an example

This paper is organized as follows. Section II represents the related work of different Medical image enhancement using FD, the proposed model is illustrated in Section III while the Experimental results are illustrated in Section IV and the conclusions are discussed in Section V.

II. Related Work

There is a trend towards methodologies that make use of the mathematical formulas Fractional Differentiation (FD) in processing different types of images.

Pu et al [6], [7], demonstrated the ability of FD in texture enhancement by proposing 6 FD masks of size nxn reaching a better result in enhancement compared to the integral-based operators, proving that FD is able of enhancing details of low frequency textured in smooth areas and preserve high-frequency edged features. Jalab et al., [8], proposed a texture enhancement method for medical images based on FD masks. Texture details within an image where variation of grey level are unnoticeable can be enhanced using FD. The enhancement mask is created by using a generalized FD operator as was described in their previous work [13], but in eight directions of the grey values equivalent to image. The size of the mask window is set as an odd natural number; preferably small to achieve better results. Later on the FD mask is applied on the pixel values by sliding from the left corner block that will give a result of eight values signifying texture information. After that the Sobel edge detector and the Gray-Level Co-occurrence Matrices (GLCM) which analyze the distribution of grey level is applied to enhanced images. To improve the results and watch the change of image texture, the method is

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repeated several times by using several fractional power values. An improvement in texture quality and sustained the edges in the image. Based on the local texture similarity Si et al [9] constructed a region of non-regular self-similar support that was used for preparing a non-regular FD mask in order to improve texture characteristics, but the fractional order needed to be adjusted to fit images with image texture complexity. Image denoising methods has also been proposed considered by [10], [11] using adaptive fractional derivatives.

III. Proposed “Detection by Classification” Model

The proposed model aims to enhance texture by incorporating the FD analysis by varying the fractional differential order (α) and fusing enhanced images to increase the detection of lesions in liver CT. Different phases have been introduced, as shown in Fig. 1, to achieve better classification. A CT image is first exposed to a preprocessing phase by applying median filter with 3x3 windows in order to gain initial noise reduction. FD is applied later on the scans using the Riesz fractional approach [12]. Texture of an image is considered one of the main image descriptors. Texture properties of an image carry very useful information that helps in the discrimination purposes. The value of (α) is adjusted to control the fractional order of differentiation ranging from 0 to 1, with a step of 0.1. This process produces 10 different FD images as shown in the example in Fig. 2.

After the FD enhancement phase, fusion is applied between the enhanced images, to improve the quality of an image and decrease uncertainty by combining multiple images as described later on. Different fusion methods have been proposed in literature [14].

Each fused image is divided into a set of non-overlapping blocks, each of the size 15*15. For better classification, the block size was chosen to cover all tumor parts in an image. The classification phase takes place on three different categories to cover diverse experimental methods. Furthermore, the classification process is applied either on the features extracted from the enhanced FD image directly; the difference gained between features extracted from original image and the enhanced FD image on feature level base; or feature extracted from the generated FD fusion images.

A. Fractional Differential (FD)

FD is an effective mathematical method for dealing with fractal problems as the integer-order differentiation can damage the texture detail feature found in an image. In smooth regions the low-frequency contour features using the FD mask are preserved maintaining non-linearly the high-frequency marginal features in region that has a reasonable change in it grey level and improves texture details in areas wherein the changes in gray level are trivial [15].

As stated earlier our or FD model was conducted from the improved Riesz fractional approach implemented by [12] by using the equation shown in (1) for creating the FD mask,

$$\frac{\partial^{v} s(x,y)}{\partial x^{v}} = -\frac{1}{2\cos\left(\frac{2\pi\alpha}{2}\right)h^{\alpha}}\sum_{k=0}^{n}\omega_k s(x-kh,y) \quad 0<\alpha<1 \qquad (1)$$

where α represent the alpha value that is used in our work as values 0.1,0.2,0.3….1.

B. Fusion of Images

In our model, average fusion was nominated and applied on the FD enhanced images. Fig. 3 represents sample of images after fusion. The fusion phase results in 10 different fused images. Where for example as shown in this figure, Img_2 is the result of the fusion between 2 FD enhanced image with α value 0.1 and 0.2 while Img_5 is the result of the fusion between 5 FD enhanced image with α values 0.1, 0.2, 0.3, 0.4 and 0.5. The output of the fusion phase results in 10 different fused images.

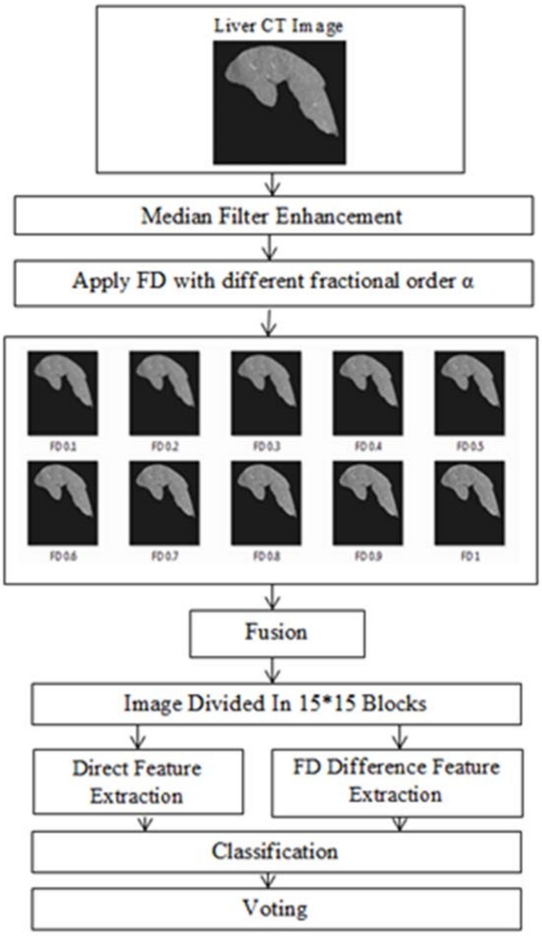

Fig. 1 Proposed Model

C. Feature Extraction

The surface and structure of an image is signified by the texture attribute [16]. It can be known as describing the positioning and local spatial variation of a pixel [17]. Texture is considered one of the important features that can perform classification between diverse organs and also between the organ and its lesion. Different features will be extracted including Grey Level Co-occurrence Matrix (GLCM), Grey Level Run Length Matrix (GLRLM), local binary patter (LBP) and Lacunarity as a preparation for the classification phase from these blocks. These features will be extracted from the divided set of blocks. According to these results, data will be grouped together to explore further relationship between similar data classifying them using Support Vector Machine (SVM) into tumor and non-tumor.

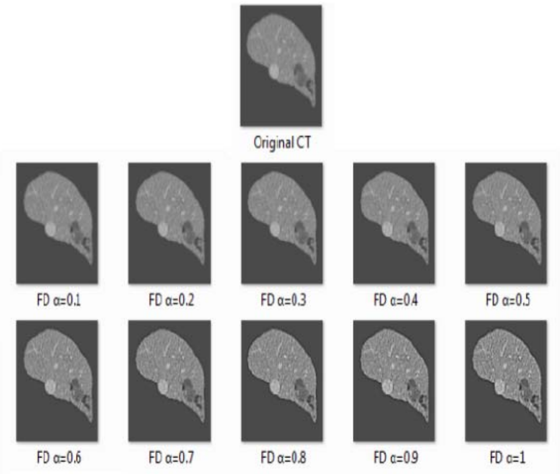

Fig. 2 Sample of CT image after applying different FD with different α value

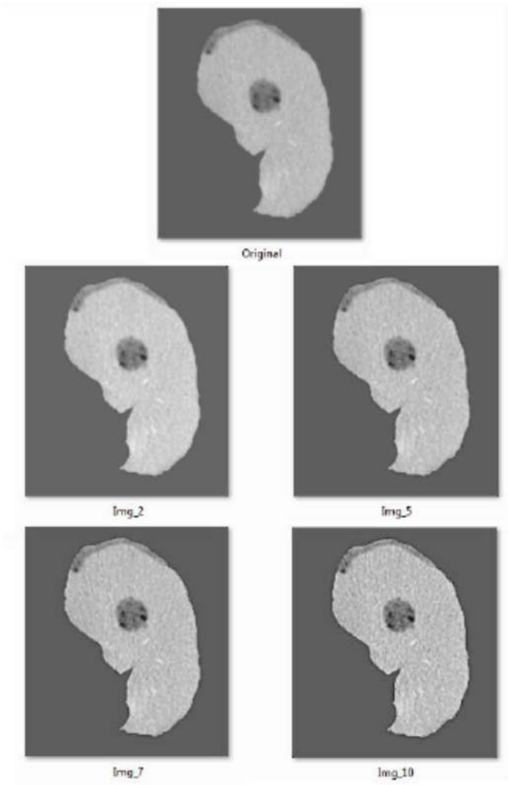

Fig. 3 Sample of Images after fusion

IV. Results and Discussion

The proposed model has been carried out on a large dataset to test its efficiency. It has been tested using samples of various patients with diverse tumor sizes and locations. Tumor detection is accomplished using SVM classifier. A dataset of several patients have been exploited as a training set. The test dataset consisted of 10 different patients each with 250 slices each. Various experiments have been applied by varying the number of features extracted and the fusion between the FD images. The blocks extracted from each CT image contained both tumor and non-tumor samples.

Different set of feature has been extracted to classify the tumor/non-tumor cells. A number of features have been extracted to classify the tumor/non-tumor cells.

- *Original image*: features have been mined directly from the enhanced CT image applying median filter only,
- *FD enhanced*: the image after applying median filter and set of different values of fractional order as explained in section 2,
- *D feature*: represents the difference of feature extracted from FD enhanced compared to the original image.
- *Fusion:* the average fusion is applied as clarified previously to obtain 10 different fused images where features are extracted directly from the non-overlapping blocks and the difference between these features and original is also obtained.

As shown in Fig. 4, experiments were first carried after applying FD only and fusion of FD images (as explained in sec 2). The results showed that only α=0.1 gave a slight improvement in classification compared to original image. Then, the accuracy started to decrease as the value of α increase, due to that FD emphasizes more hidden details as we increase the differential order that sometimes might give the effect of noise. It can also be observed that the fusion of FD images can provide higher accuracy rate than the individual FD enhanced images. Hence, we investigated that further.

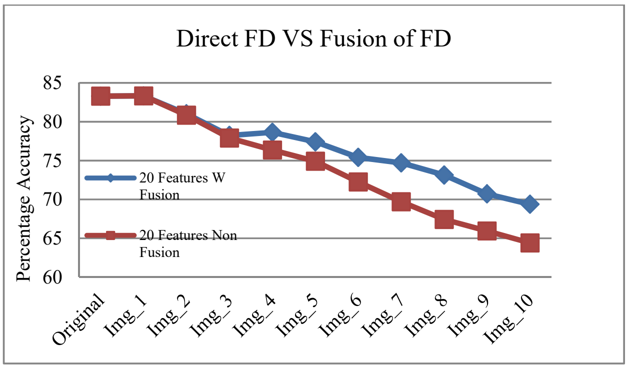

Fig. 4 Classification accuracy between extracting features from FD image and proposed Fusion of images

More experiments were carried out to measure the detection performance of the voting of the classifications in the different phases, as explained in our proposed model. Fig. 5 shows the results, Better results were achieved, especially in fusion phase of the difference in the FD images reaching a 90% positive classification. These results clarify that generating a difference of features, from fused image and original image, can improve the targeted classification.

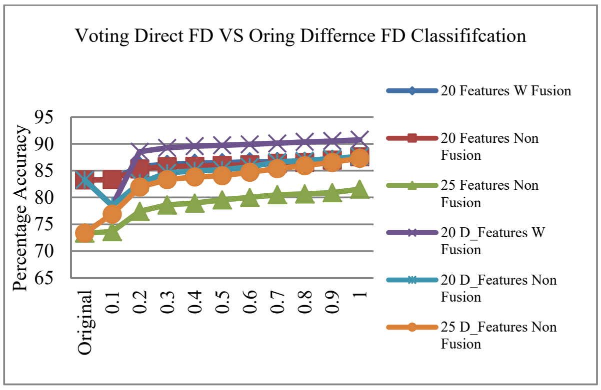

Fig. 5 Results comparison between Voting Direct FD with and without fusion, Voting Difference feature FD Classification with and without fusion, varying the number of feature extracted

Further improvements were accomplished by combining the good performance of voting of direct fusion of FD images and voting of difference of FD images. Classification results outperformed previous experiments resulting in accuracy of 93.8%, especially in fusion of FD images as depicted in Fig. 6. As the value of α increase with the fusion of the enhanced output images, more enhanced features are gained resulting in the gradual rise in classification accuracy, compared to the classification on original CT image.

From the experiments we can conclude that classifying fusion between FD image and voting them with the classification of the FD difference features of fusion images can improve the detection accuracy of tumors by 10 %.This indicates that FD can enhance the image, but with the fusion and using the FD in a different way through extracting the difference of features

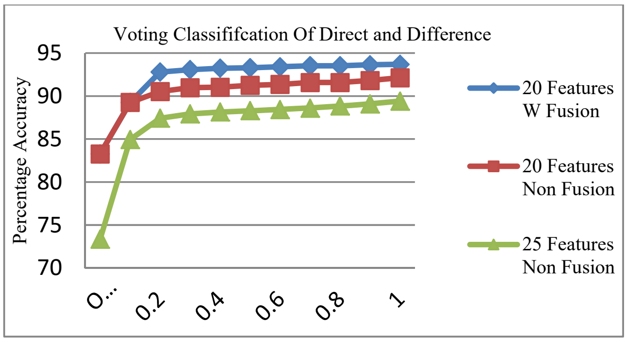

Fig. 6 Voting Classification of Direct fusion classification and Difference FD Feature classification

V. Conclusion

We have represented an approach that utilizes the FD for enhancing the features of Liver CT image to increase the accuracy of detection by classifying tumor/non-tumor regions. This is accomplished by fusing the enhanced images and extracting targeted features directly from them and from the difference of FD image. The proposed model showed promising results and achieved detection accuracy of 93.8%, which is more than 10% improvement compared to detection from the original images. In our future work, we are aiming to raise the accuracy of detection by exploring different fusion methods based on feature level with varying the block size, to implement a novel automatic segmentation of lesions method.

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