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Detection of Alzhemier's Disease Using Fractional Edge Detection

Reju John[1], Nissan Kunju[2]
[1]*(Department of Electronics &Communication, College of engineering Cherthala, India)*
[2]*(Department of Electronics & Communication, T.K.M College of engineering Kollam, India)*

Abstract: *The work consist of two phases. The first phase of the work aims at finding out the optimized value of the fraction used in fractional filtering for image enhancement techniques in digital image processing. The work is done on MATLAB platform. The work starts with a comparative study of fractional order filter and integer order kernel filters like Sobel and Prewitt filters, used for edge detection and boundary detection of various digital images. With the view of applying fractional filtering in medical images, the work is done by utilizing Magnetic Resonance Imaging (MRI). The noise performances of these filters are analyzed upon the addition of random Gaussian noise. The mean square error (MSE) and peak signal to noise ratio (PSNR) of the detected images are adopted as evaluation methods for comparison. The visual comparison of the filters capability in medical image enhancement is presented in this project. It has been proved that fractional filter outperforms integer order filters. In the second phase fractional filtering with the optimized value of the fraction is utilized for the detection of Alzheimer disease (AD) from MRI scan of the brain. Based on MSE and PSNR optimized value for the fraction used in fractional filtering is found out to be 0.5. The fractional filter with fraction equal to 0.5 is used to detect Alzheimer's disease. This could progressively help in understanding and treating Alzheimer's disease.*

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I. Introduction

The image processing applications are invading people's lives. Being an important area of information technology, image processing problems have been a research focus for decades. Edge detection is a main part in digital image processing, as it is considered a preliminary step in image analysis and pattern recognition. Edges are the sudden changes of discontinuities in an image. They occur at the boundary between two different intensity regions in the image [1]. Edge detection methods mainly use integer-order filters, namely first order derivative of the gradient operator or the second order derivative Laplacian operator. These operators are considered to be noise sensitive. How to detect the image edges while reducing noise is a core in the edge detection study [2]. The use of fractional order calculus in designing edge detection fractional filters greatly enhances the edge detection methodology, regarding noise sensitivity and the controllability of image features through targeting certain frequency components. Fractional calculus, also called non integer order calculus, is a generalization of the integer order calculus. The concept of fractional calculus appeared at the same era with the integer order calculus early in the nineteenth century. Due to the efforts of many scientists, in the past two hundred years, fractional calculus has developed to be a standalone pure mathematical branch [3]. Integer Order Kernel filters are mainly used for edge detection purpose in image processing.

The Problems associated with the above filters are: Noise sensitive and Possibilities of the loss of image details while using especially first order filters. In image processing, it was found that the fractional differential operators have many advantages over the integer order ones. The fractional derivative involves infinite number of terms, unlike the integer derivative which involves just finite terms. Thus, the fractional derivative is considered to be a global operator. The fractional operator can consider more neighboring pixels information, extracting more image texture details. There exist different definitions of fractional differentiation. They are Grunwald-Letnikovs (G-L) definition, Riemann-Liouvilles definition and Caputos definition [4]. In this Project G-L definition is used for developing the mask required for fractional filtering which is a solution to the problem defined. The aim of the project is to optimize fractional filtering and thereby applying the same for the early detection of Alzheimer's disease. Following are the aim and objectives of the work:
To perform a comparative study of fractional filter, and integer order filter in edge detection of a given MRI image.

The performance of the filters is to be evaluated based on MSE and PSNR values of the filtered image after adding a random Gaussian noise on the original image.
To find the optimum value of the fraction.

II. Fractional Calculus Based on G-L Definition

Fractional calculus is also called as non integer order calculus, is considered as a platitude of integer order calculus. The concept of fractional calculus appeared at the same era as that of integer order calculus early in nineteenth century. Due to the efforts of many scientists, in the past two hundred years, fractional calculus has developed to be a standalone pure mathematical branch [3],[4]. In image processing, it was found that the fractional differential operators have many advantages over the integer order ones. The fractional derivative involves infinite number of terms, unlike the integer derivative which involves just finite terms. Thus, it is considered to be a global operator. There exist different definitions of fractional differentiation. They are Grunwald-Letnikovs (G-L) definition, Riemann-Liouvilles definition and Caputos definition . In this project Grunwald-Letnikovs (G-L) definition is used to develop a fractional order filter. It is defined as follows:

$$\frac{df(x)}{d(x)} = \lim_{h\to\infty} \frac{f(x)-f(x-h)}{h} \quad \ldots\ldots\ldots 1$$

By Taylors theorem,

$$\exp(hx) * f(x) = f(x+h) \ldots\ldots\ldots 2$$

$$\frac{df(x)}{dx} = \lim_{h\to\infty} \left(\frac{1-\exp(hx)}{h}\right) f(x) \ldots\ldots\ldots 3$$

$$D^m = \lim_{h\to\infty} \left(\frac{1-\exp(hx)}{h}\right)^m \ldots\ldots\ldots 4$$

$$(D)\,m = \lim_{h\to\infty} \frac{1}{h}(1 - m\exp(-hx) + \frac{1}{2!}m(m-1)\exp(-hx) - \frac{1}{3!}m(m-1)(m-2) + \ldots\ldots 5$$

From equation (5) it is clear that the fractional derivative has boundless number of terms, unlike the integer derivative which involves just finite terms. The fractional operator can consider more neighboring pixels information, extracting more image texture details.

By the use of the G-L definition, the classical first-order Sobel operator is generalized to constitute a fractional-order [5] operator for edge detection The fractional order filter mask (from G-L definition) used in this project is shown in Table 1.

Table 1 Fractional Order Filter Mask

$((\alpha^2-\alpha)/4$	$(\alpha^2-\alpha)/2$	$(\alpha^2-\alpha)/4$
$-(\alpha)/2$	$-\alpha$	$-(\alpha)/2$
$1/2$	1	½

III. Result and Discussions

The simulation is done in MATLAB software. The study was conducted on MRI images. As the first step a random Gaussian noise with mean equal to 0 and variance equal 0.003 variance is added to the gray scale image of the MRI scan and the masks (both First order and fractional Order Sobel Mask) were used for detecting the edges of the noisy image. The images obtained in the case of fractional filtering extracts more image texture details. It is because of the fact that it can consider more neighbouring pixels information.

Optimization of Fractional filter

The detection was performed with various values of the fraction α on a number of MRI images and each is quantitatively compared with First order filter. Two quantitative parameters were used to compare the performance of integer order filter and fractional order filter:

- MSE- The first parameter is the mean square error .
- PSNR- The Peak signal to noise ratio of the edge detected noisy images is found out by the expression $PSNR = 10 \times \log(256^2/MSE)$.

The MSE and PSNR values were obtained for Sobel, Prewitt first order filters and fractional order with various fractions.The average of those values for different MRI scans are tabulated in the table shown in table 2.

Table 2 Comparative study of filters in terms of MSE and PSNR

Sl.no.	Filter Type	MSE	PSNR
1	Sobel First Order	7380	9.48
2	fractional order with α=0.1	13383	6.9
3	fractional order with α=0.28	8136	9.06

4	fractional order with α=0.5	2934	13.49
5	fractional order with α=0.7	4546	11.59

From this analysis it was concluded that for a fractional filter, at 0.5 the MSE is at its minimum value and PSNR at its maximum value. Hence the fraction 0.5 is found to be the optimized value.

Methodology used in detection of Alzheimer's Disease

The MRI scan datasets are obtained from www.oasis-brains.org. The data format is analyse format. The T2 axial MRI scan is extracted from the dataset. A series of image processing techniques are applied to the MRI before the volumetric measurement of gray matter and white matter. A sample MRI image of a 16 year old male is taken into consideration as shown in fig 1.

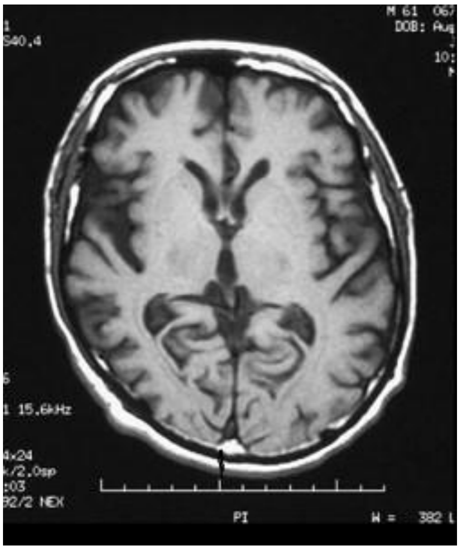

Fig. 1 MRI image of a 16 year old male. Retrieved from www.oasis-brains.org .

Boundary detection

One of the initial steps to analyze the MRI is to isolate gray matter and white matter. To do this the cranium or the skull has to be removed. This is done by boundary detection algorithm till the region of interest was visible. The skull removed image of the above sample MRI image is shown in fig 2.

Segmentation

Edge detection method was adopted using the optimized fractional filter to separate the gray matter from the boundary detected image. We have proved that at fraction 0.5 the fractional filter performs at its best [11]. The mask used for fractional filter by setting the fraction to 0.5 is shown in Table 3. By proper thresholding gray matter is obtained as shown in Fig.3.

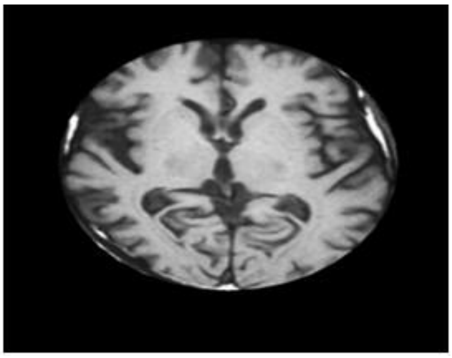

Fig. 2 Boundary Detected Image MRI image

Table 3 Fractional Order Filter Mask with $\alpha = 0.5$

0.0625	0.125	0.0625
-0.25	-0.5	-0.25
0.5	1	0.5

Fig. 3 Segmented image.

Volume Calculation

Using MATLAB commands the volume of gray matter and white matter were evaluated. Based on the volumetric difference (D) between gray matter and white matter brain condition were classified [6] as follows: D¡ 60 mm3 - Healthy Brain 60¡ D ¡100 mm3 - Chance of normal Atrophy D¿100 mm3 - Chance of AD
The above steps were carried out for different MRI scan of different cases. The result and inference obtained are tabulated in table 4

Table 4 Numerical Results

Sl.no.	Age	Gray matter Volume	White matter volume	Volume difference	Comment
1	16	382	438	50	Healthy
2	62	344	415	71	Chance of Atrophy
3	65	261	561	300	Chance of AD
4	63	495	536	41	Healthy

IV. Conclusions

Medical Imaging has played a very important role in the study and diagnosis of a lot of diseases over the past four decades. One of which is Alzheimer disease (AD), specially the use of the magnetic resonance imaging (MRI) in detecting its progress. The AD is a progressive degenerative disease of the brain that leads to dementia. It leads to nerve cell death and tissue loss throughout the brain. Over time, the brain shrinks dramatically, especially in the hippocampus, affecting nearly all the brain functions. Also, the ventricles (fluid-filled spaces within the brain) grow larger. These changes can be visually noticed by the MRI. The fractional filter can be used for edge detection in analyzing such progressions thereby it can be an aid for the early detection of AD.

Limitation

One cannot arrive at a clear demarcation to distinguish AD and normal atrophy when the difference in gray matter and white matter volume lies on the borderline. As detailed in [6] the decrease rate in the case of AD is 1% per year as compared to the sluggish rate in the case of a normal atrophy. The limitation can be done away with a repeated check up with in a gap of 6 months.

Future Scope

One of the major externally unnoticeable symptoms in an AD patient is the brain shrinkage especially gray matter volume. The fractional filter can be used for edge detection in analyzing such progressions thereby it can be an aid for the early detection of AD. This can serve as a teaching aid for the medical students to validate their understandings. The use of image processing for medical diagnosis is increasing extensively during these days. The work moves in a direction beneficial to the medical community.

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