AL- Rafidain University College

PISSN: (1681-6870); EISSN: (2790-2293)

Journal of AL-Rafidain University College for Sciences

Available online at: https://www.jrucs.iq

JRUCS

Journal of AL-Rafidain University College for Sciences

Image Processing Techniques for COVID-19 Detection in Chest CT Scan Images

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Article Information

Article History:
Received: June, 27, 2022
Accepted: October, 26, 2022
Available Online: December, 31, 2022

Keywords:
COVID-19, median filter, Fractal Dimension, histogram equalization, Euler number method.

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Abstract

COVID-19 virus is a disease that has spread around the world recently. Early diagnosis of the disease leads us to the opportunity to treat patients faster to reduce its spread in the community. The CT scan image is one of the routines used to diagnose the COVID-19 diseases in an efficient manner and in a faster time. Fractal Dimension which mean (fragmented or irregular) used in wide range of image processing and analysis applications to get the self- similarity of images. To classify textures, combine images, segment and compress images and to generate incredibly complex and good-looking images, the Fractal Dimension method is used. Moreover, Euler method uses features to explain the structural property caused by noise in binary images. It also describes the topological features and analyze the texture of images. In this paper, a method is proposed to obtain the features of CT scan images for COVID-19 by using a hybrid technique called Fractal Dimension Euler (FDE), which merges the two methods of image processing (Fractal Dimension method and Euler Number Method). The two algorithms aim to segment the CT-scan images for the chest to distinguish between the affected and uninfected area of the chest to detect the COVID-19. The results of the proposed approach were very useful in comparison with another approach, the FD method was applied to CT scan images for COVID- 19 using a method called box counting. After that, the Euler method was used to distinguish between foreground and background by using a threshold value. The best threshold value was (255) which achieved the finest result.

doi: https://doi.org/10.55562/jrucs.v52i1.554

1. Introduction

Coronavirus Disease 2019 (COVID-19) pandemic has overloaded worldwide healthcare systems with an exponential infection rate. Diagnosis of COVID-19 is carried out by "Reverse Transcription Polymerase Chain Reaction (RT-PCR)", which suffers from delay, low sensitivity, and low accuracy [1-3]. Early diagnosis of COVID-19 leads to the chances for successful treatment of infected patients and also the chances of spreading COVID-19 in the community will be reduced. Computed tomography (CT) known as radiography images used as a routine technique for diagnosing some lung diseases [4], Tuberculosis [5] as well as for the detection of COVID-19[6-8]. Tests of CT scans have elevated sensitivity than RT-PCR tests. This result is validated by the work in [9], since that RT-PCR tests and CT scans obtain a sensitivity of 71% and 98%, respectively. In [10, 11] CT could be used to objectively and speedily estimate the rigorousness of pulmonary membership in COVID-19 patients, which is statistically validated [12]. For the patients who are contaminated with COVID-19, CT images can present early diagnosis and professional estimate monitoring at a low cost. An automated way for conclusion of COVID-19 on CT can velocity up many tasks and the application of health check treatments [13]. An important element of image analysis and processing is texture. FD of the image is not concerned with a measure image surface irregularities complexity of image but is also invariant for change in scale and resolution. Human visual perception of the roughness of an image surface is consistent with FD. If the FD of an image is greater, the image surface is rougher too, and vice versa[14] .

Segmentation method depends basically on image which is available to be segmented. The commonly method which uses a threshold value is the histogram. However, the accurate threshold is not guaranteed for this method. For this reason, the Euler number used for real time applications for segmentation of images.

In 2007, Berke, J. [15], proposed a new mathematical concept named the author spectral fractal dimension' as well as used the algorithms to compute fractal dimension in an uncomplicated way. The method applied and proven that via the Box method fractal dimension and appropriate measures choosing which results in practically applicable if an optional number of dimensions selected . In 2015, Nadia M. G. Al-Saidi et al [16], presented in a work a new method for fuzzy fractal dimension. The experiments on a set of natural texture images have proven its efficiency and accuracy, and an acceptable result is found. It also has promising performance offers when it is tested on some types of noises to display good robustness to them. In 2019, Ebenezer Jangam, A. Chandrasekhar Rao, et al [17], proposed a work for use of Euler number-based thresholding method for segmentation of the lung region from CXR images. To improve the accuracy of the segmentation, morphological operations and greedy snakes are used. The proposed method gives high accuracy and high performance in comparison the state of art methods . In 2020, Ayub Ahmed, Bashdar Salam1, et al [18], presented in a work three numerical techniques used for diagnosis of this disease, they are Runge–Kutta method of order two (RK2), of order four (RK4) and Euler's method. The suggested numerical techniques results and providing estimated solutions give important explanation answers to this global issue. To estimate the number of susceptible, infected, recovered, and quarantined individuals in the future numerical results may use. Thus, the logistic model can investigate the forecasting epidemic size, as well as the suggested model is a realistic description of this epidemic disease. In 2021, Elbakary, M.I., and Iftekharuddin, K. [19], proposed a method to segment the area of lung to generate lung mask after the cut off high-intensity areas are removed from the neighboring ribs in the input CT image by using the most advantageous algorithm for segmentation and morphological operations. After that, to notice areas of infectivity in the lung the proposed technique employs the segmented lung mask. To differentiate among disease and non-disease region in the lung, the difference in the gray level of each region is calculated and used as a feature to discover the area of illness which are illustrious by small difference compared to Non-COVID-19 area. The precision of detection for Covid-19 images is 91.7% and that for Non-Covid-19 images is 91.7%, correspondingly[19].

This paper proposed a method to obtain the features of CT scan images for COVID-19 by using a hybrid technique called Fractal Dimension Euler (FDE), which merges the two methods of image processing (Fractal Dimension Method and Euler Number Method).

The rest of this paper is organized as follows: Section 2 illustrates the theoretical background. The proposed method is denoted in section 3 . Experimental results on various types of CT scan images are represented in section 4 to obtain the efficiency of our method. In section 5, the concluding remarks are written.

2. Theoretical Background

One of the method to study the difference of image intensity elements (pixel) values is texture analysis. For proper classification, can be analyzed physical quantities at scales smaller than the scales of interest if we deal's with medical images. FD method is used to transform the image intensities for the purpose of texture analysis. Image segmentation and image compression in addition to image processing can be considered as applications of fractal analysis [20].

To calculate the fractal dimension (FD) of an image, there are different approaches including the differential box-counting algorithm (DBC), the binary box-counting algorithm (BBC), and its differential extensions [21], additionally the multitude of other image fractal descriptors [22].

The BBC FD classical estimator requires a pre-processing step of transforming the gray-scale images into binary values so that the threshold value is used to get the result [23, 24].

"Square" boxes method requires resizing the image such that a square dimension like the length calculated in the amount of pixels, was of a power of two. The square image in this method can be similarly partitioned into four quadrants and each consequent quadrant must be partitioned into four quadrants, and so on. The color image is converted into grayscale, with grayness intensity for each pixel depending on the threshold value to create an image in black and white color (binary image). A job of the box volume and the length of the "box" represent the number of boxes containing "black" pixels. To calculate and plott all these points, the natural log must be used.

The ln(pixel-size of the box) points versus ln(number of boxes) were drawn and the FD was founded by the slope of the best fit line for the plotted points[25].

A binary image is an array of two-dimension extracted from a gray level image that has been determined at two levels, 0 and 1. Level 0 represents the background with no object and level 1 denoted the object in the image. For each observed object in the image, can be computed the geometric and topological features. One method to calculate these features is called the Euler number. In the binary image, the Euler number will not change when the image is flexed or stretched like an elastic band. So, this method is considered a forceful feature of a binary image and it can be used in different applications like robot vision, shadow detection, reflectance-based object recognition, cell images in medical diagnosis, and document image processing[26].

The Euler number of a binary image can be represented mathematically by the following equation:

$$\boldsymbol{E = N - H} \tag{1}$$

Where H is the number of holes in the image (regions of the image's background) and N is the number of connected components regions of the image (number of the object) [27].

3. The Proposed Method

The proposed method in this paper consists of two methods, the first method is defined as the fractal dimension method, and the second is called the Euler number method. The images were acquired from the dataset for CT images of the COVID-19 pandemic. The website for these images is" https://www.eibir.org/covid-19-imaging-datasets", and the dataset with the name UCSD COVID- CT database contains 349 images from 216 patients. The image with PNG format, 512 x 512 size, and grayscale value.

The FD approach

At the beginning of the process, the noise in the image was reduced using the median filter, which is a nonlinear digital filtering method, often used to eliminate noise. After that, the CT image for COVID-19 can be segmented by applying the FD method. FD method will be carried out on the grayscale image to partition the image into self-similar parts of the image using the technique called box-counting. In the box-counting technique, the image is broken into smaller and smaller pieces (small squares), and analyzing the pieces at each smaller scale. Since the digital images (CT-Scan) used in this research are square images, so when applied the box-counting method on these images, will allow dividing the square image to be equally partitioned (four quadrants) and each following quadrant can be divided into four quadrants, and so on

To apply the box-counting method, the FD calculating is done by the following equation:

$$\mathbf{D} = \log(N) / \log(S) \quad (2)$$

Where N is the number of the auto-similar parts, in which an object in an image can be subdivided and S is the scaling, The algorithm used for computing the FD approach by applying Box counting is as follows [28]:

1. Image segmentation
2. Halving the image along the vertical and horizontal symmetry axis
3. Pixels valuable will be examination in the box
4. The number of boxes are saved with valuable pixels
5. Repeat 2-4 until the shorter side is only 1 pixel.

An example of the FD method is notice in the Figure (1).

(a) (b)

Figure 1: (a):original image, (b) image process with FD method

Euler Method

Euler method applying in this paper on grayscale image for COVID-19 patients to (segment) or convert the image from grayscale to binary image depending on the value of the threshold.

At the beginning of this approach, the histogram equalization is used to improve the dissimilarity of images by transforming the values in an intensity image; on the other hand, it spreads out the most frequent pixel intensity values or stretches out the intensity range of the image, as a result, the histogram of the output image approximately matches a specified histogram.

(a) (b)

Figure 2: (a):original image, (b) image process with Euler method

After applying the histogram equalization, the Euler number method will be applied to the gray scale image depending on equation (1) by determining the value of the threshold as (255). This value of the threshold leads to distinguishing the object (foreground) from the background. The object in this image will contain the COVID-19 disease region. Figure (2) illustrates Euler method.

The following diagram represents the proposed approach:

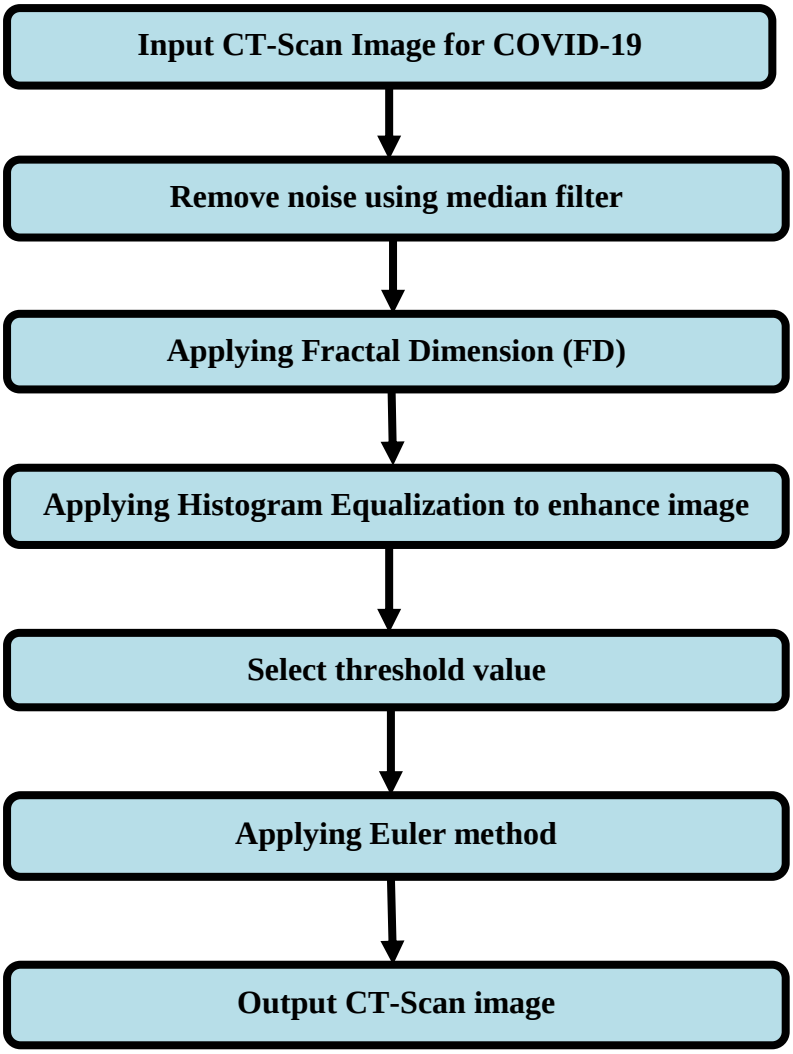

Figure 3: Diagram of the FDE method.

4. Experimental Results

In this paper, the results were performed on a set of infected and uninfected images (20 infected and 20 unaffected images) and samples were taken (4 images for each case). The result of the proposed method was very useful so that the feature of chest image can be seen in clearly for infected images. The FD method was applied to CT scan image for COVID- 19 using a method called box-counting which divided the square image into subsequent with different scales to determine the region of disease. After that, the threshold value is used to segment the image to make a distinction between the foreground and background in the image. Different value of threshold was exuded for a process called the Euler method. The best threshold value was (255) which achieved the finest result. The FDE results shown in the figure 4.

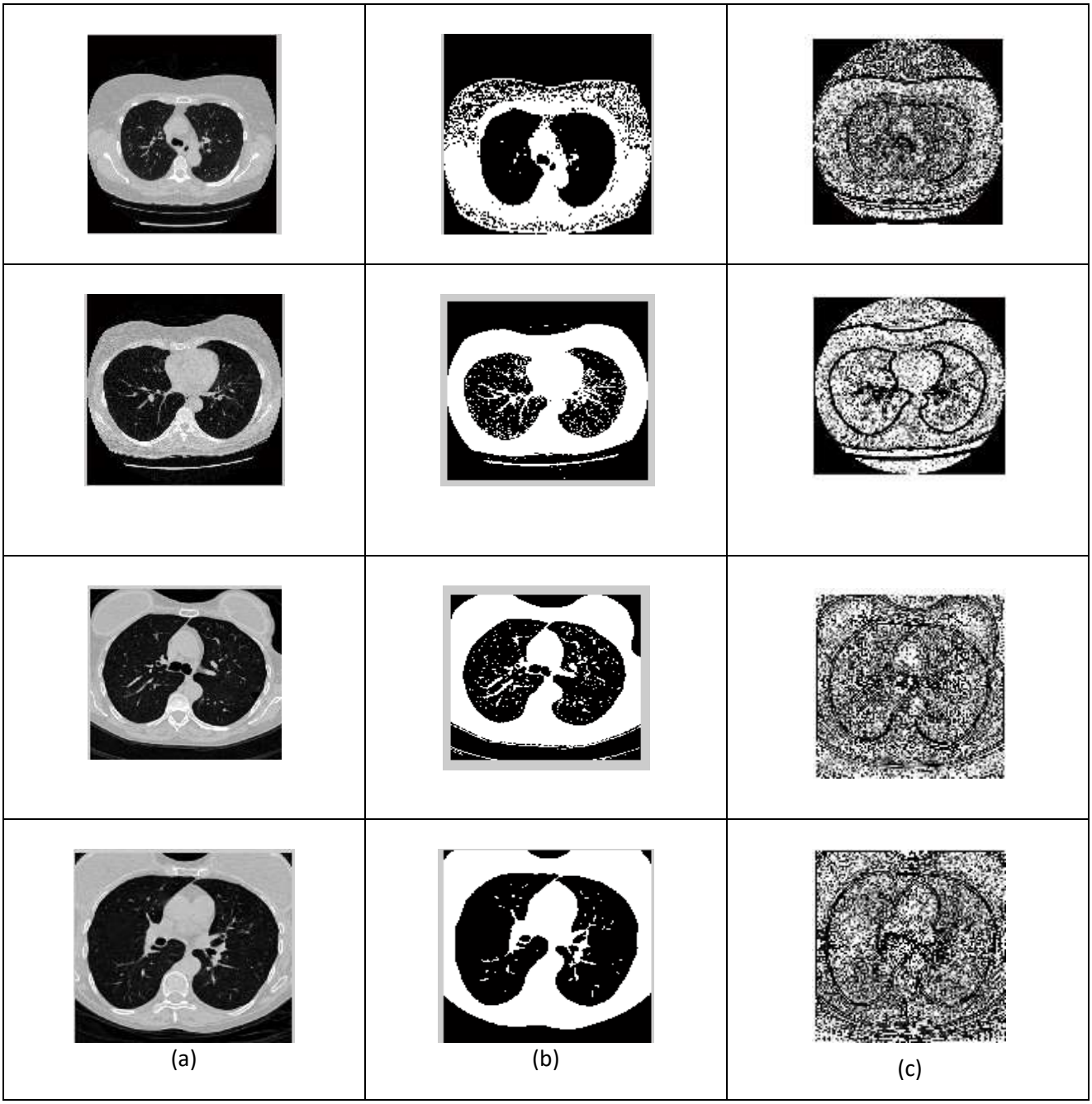

Figure 4: (a) original image with COVID-19 , (b) image processed with the Euler method, (c) image processed with the FDE method.

As seen in Figure 4, the result images from the proposed method was compared with the Euler method [25] to extract the feature of image and segment the image of chest region. After evaluating the results of the two methods, it was noted that the images produced by the proposed method has achieved the best segmentation feature (more details) as compared with the image produced by the Euler method

5. Conclusion

In this paper, we presented a hybrid technique for discovering COVID-19 in CT scan images called the FDE. This technique is composed of two approaches; one is called the Fractal dimension method and the other Euler number method.

The FDE method has the best segmentation feature as compare with other related work so that the feature of the image turned out better, especially after converting the image to a binary image.

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مجلة كلية الرافدين الجامعة للعلوم (2022)؛ العدد 52؛ 218- 226

AL- Rafidain University College

PISSN: (1681-6870); EISSN: (2790-2293)

مجلة كلية الرافدين الجامعة للعلوم

Available online at: https://www.jrucs.iq

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Journal of AL-Rafidain University College for Sciences

تقنيات معالجة الصور لاكتشاف COVID-19 في صور مسح الصدر بالأشعة المقطعية

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المستخلص

في الآونة الأخيرة انتشر فيروس كورونا حول العالم، التشخيص المبكر للمرض يقودنا إلى فرصة علاج المرضى بشكل أسرع لتقليل انتشاره في المجتمع. تعد صورة الأشعة المقطعية أحد الإجراءات الروتينية المستخدمة لتشخيص أمراض COVID-19 بطريقة فعالة وفي وقت أسرع. البعد الكسوري الذي يعني (مجزأ أو غير منتظم) يستخدم في مجموعة واسعة من تطبيقات معالجة الصور وتحليلها للحصول على التشابه الذاتي للصور. يتم استخدام البعد الكسوري لتصنيف الأنسجة، دمج الصور، تقسيم الصور وضغطها لإنشاء صور معقدة للغاية وذات مظهر جيد. علاوة على ذلك، فإن طريقة أويلر تستخدم السمات لشرح الخاصية الهيكلية التي تسببها الضوضاء في الصور الثنائية. أيضًا، يمكن وصف السمات الطوبولوجية وتحليل تركيب الصور بطريقة أويلر. في هذا البحث، تم اقتراح طريقة للحصول على خصائص صور الأشعة المقطعية لـ COVID-19 باستخدام تقنية هجينة تسمى Fractal Dimension Euler (FDE)، والتي تدمج طريقتين لمعالجة الصور (Fractal Dimension Method و Euler Number Method) . تهدف الخوارزميتان إلى تقسيم صور التصوير المقطعي المحوسب لصور الصدر للتمييز بين المنطقة المصابة وغير المصابة من الصدر لغرض اكتشاف COVID-19. نتائج النهج المقترح كانت مفيدة للغاية بعد مقارنتها بنهج آخر، لذلك تم تطبيق طريقة FD على صور التصوير المقطعي المحوسب لـ COVID- 19 باستخدام طريقة تسمى العد الصندوقي. بعد ذلك، تم استخدام طريقة أويلر للتمييز بين المقدمة والخلفية باستخدام قيمة العتبة . أفضل قيمة عتبة كانت (255) والتي حققت أفضل نتيجة.

معلومات البحث

تواريخ البحث:
تاريخ تقديم البحث: 2022/6/27
تاريخ قبول البحث: 2022/10/26
تاريخ رفع البحث على الموقع: 2022/12/31

الكلمات المفتاحية:
COVID-19، مرشح متوسط، بعد كسوري، معادلة الرسم البياني، طريقة رقم أويلر.

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doi: https://doi.org/10.55562/jrucs.v52i1.554