A novel method for Osteoporosis detection: A case study on human X-Ray images

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ABSTRACT: *Osteoporosis is a medical condition in which the bone loses minerals such as calcium, vitamins and phosphate. This results in reduction of bone mineral density (BMD) and hence, bones become brittle, porous and fragile leading to breakage. There can be many causes of osteoporosis such as hormonal imbalance, lack of calcium and vitamin D, thyroid conditions, sedentary lifestyles, food disorder etc. It is necessary for a person to diagnose this disease in early stage because it leads to fracture of bones, especially in the spine, hip, toe, elbow and wrists. Medical science provides many imaging modalities like CT, MRI, and X-Ray for diagnosis of osteoporosis. An X-Ray image is the basic imaging technology to detect osteoporosis from human bones. Orthopaedics doctors are generally do visual interpretation of X-Ray image to classify between the normal and osteoporotic bone, but this may be inaccurate due to image blurring, improper light, jaggies etc. In literature, many researchers have suggested many methods to detect osteoporosis from X-Ray images of human. No method is perfect, accuracy and specificity of the algorithm is to be improved for further research. In this research paper, we have proposed an improved method, which is called ODFA (osteoporosis detection using fractal analysis) to detect osteoporosis from human being's X-Ray images based on Gaussian filter, Histogram equalization and fractal analysis. The achieved accuracy, sensitivity and specificity of this method are remarkable as compared to other methods. We have also presented a comprehensive comparison of our proposed method with some latest methods/algorithms of osteoporosis detection from X-Ray images. Further, we have found that our proposed method is superior in terms of accuracy, sensitivity and specificity.*

Key Words: *Osteoporosis, X-Ray, Sensitivity, BMD, Specificity, Accuracy.*

I. Introduction

Medical image analysis is one of the evolving and innovative areas to enhance the accuracy of diseases diagnose and to provide better treatment to the patient. The ultimate goal of Computer Aided Diseases Diagnoses (CADD) system is to diagnose diseases from medical images in digital form [1]. Osteoporosis is the most common metabolic bone disease, with a wide distribution among the elderly [20]. Osteoporosis is a disease characterized by thinning and deterioration of bone tissue with loss of calcification and density.
Osteoporosis can progress over time. This can cause the bone to become fragile, increasingly porous (as the name of the disease would suggest), and to break more easily. When viewed microscopically, healthy bone looks somewhat like a honeycomb. In cases where osteoporosis is present, the holes and spaces in the honeycomb appear much bigger than those found in a healthy bone. Women and older adults are more at risk for developing osteoporosis. Heredity, low body weight, and chronic use of certain medications (such as steroids) are also risk factors for the disease. Lifting, bending, bumping into furniture and even sneezing can cause a bone to break in people affected by osteoporosis. Fractures of the hip, spine or wrist are most common, but other bones are also susceptible to breaks. Osteoporosis can be present for years without any noticeable symptoms, but signs can include: Severe back pain, Loss of height over time, a stooped posture and Bone fractures from minor injury. Fig.1 shows normal X-Ray image in left side and an X-Ray image with bone osteoporosis disease in right side. (Courtesy: google.com)

Fig. 1: Arm of human being with osteoporosis.

In this paper, we have proposed a new method entitled as ODFA based on the Gaussian Filter and Fractal Analysis that used to characterize osteoporosis. The purpose of the research is to increase the accuracy of clinical diagnostic by applying the fractal method on the bone x-ray images. In this method, the images data, which in spatial domain, was transformed to the frequency domain using Fourier Transformation. The paper is organized as follows: Section 2 discusses related work on methods/algorithms to detect osteoporosis from human X-Ray images. Section 3 describes methodology to detect osteoporosis from human X-Ray images which includes background of fractal analysis, Gaussian filter, flowchart of proposed ODFA algorithm and discussion on comparison metrics. Section 4 describes series of steps to for proposed ODFA method. In Section 5, we have conducted experiments in terms of comparison and discussed experimental results. Finally, the paper is concluded in Section 6 with future attempts to be made.

II. Relate Work

In Computerized Medical Image Diagnostic System, an X-Ray image analysis is a crucial process in which an X-Ray image of human body is passed as an input and it generates output to support decision of medical practitioners. Many researchers have shown their interest to detect osteoporosis from human X-Ray images. Following paragraphs discuss about related work of some latest methods/algorithms to detect osteoporosis from human X-Ray images.

Venkatesh et al. [2] have proposed a method to detect Osteoporosis from Hip Region of human. They have not considered other parts of human body such as writs, elbow, shoulder etc. Dr. Pravin et al. [3] have come up an idea to detect osteoporosis from X-Ray images based on 1st order Texture Parameters. Accuracy is only 66.66%. Dr.Shubangi et al. [4] have presented survey on different osteoporosis detection algorithms such as KNN classifier, Fuzzy Expert System, BMD calculation and Mathematical Morphological Approach. Authors of paper [5] have developed a texture based method to detect osteoporosis from radiographic images. But, they have considered only 87 bone radiograph images. The paper [6] presents a combination of the periodical and panoramic images for osteoporosis detection. The algorithm achieved accuracy rate 73.33%, sensitivity rate 72.23% and specificity rate 72.23% for data testing.

Paper [7] presents an algorithm based on BONE DENSITOMETER – SIMULATION. This method is very time consuming to detect osteoporosis. Arment et al. [8] have devised an algorithm to detect osteoporosis based on dual-frequency ultrasonometer. They have achieved 76% sensitivity and 70% specificity. Authors of paper [9] present a computer system to detect erosions and osteophytes from hand radiographs. Specificity is 70%. In this system, sensitivity and the specificity equal around 70%. Paper [10] proposes a method for extracting morphological information enabling the description of bone structure from radiological images of the calcaneus. It is highly recommended for dental images. Authors of paper [11] have proposed a method to predict osteoarthritis in knee and hand joints. They have not considered any evaluation metrics or parameters. Paper [12] proposed a fuzzy inference system for osteoporosis detection. They have considered 20 X-Ray images of different age groups and achieved 78.90% mean bone density. Authors of paper [13] have presented Consensus document on osteoporosis in males patients only. Tomlison et al. [14] have explained that there are many challenges to develop a computerized system to detect osteoporosis from X-Ray images and major is to improve the accuracy. Riandini et al. [15] have used a combined approach K-Nearest Neighbor (KNN) and feature extraction techniques Gray Level Co-occurrence Matrix (GLCM) to classify osteoporosis from throax X-Ray images but, they have considered only 46 throax X-Ray images. Authors of paper [21] have presented Active Appearance Models to early detect osteoporosis and they have achieved accuracy 81.2%. Reshmalakshmi [22] proposed a fuzzy inference framework for diagnosis of osteoporosis disease in the field of medical imaging. They have conducted experiments on 20 patients.

It is cleared from the above presented extensive literature review, that no method/algorithm is perfect and to detect osteoporosis from human X-Ray images. Each and every method achieves different accuracy, precision, specificity or sensitivity. It gives us relentlessly motivation to work in the field of osteoporosis detection from human X-Ray image to increase the accuracy of clinical diagnostic by applying the fractal method on the bone x-ray images and here, in this paper we have presented an improved method for Osteoporosis detection from X-Ray images based on Gaussian filter and fractal analysis.

III. Methodology

In this section, we have discussed methodology of proposed ODFA method for osteoporosis detection. We have divided it into three sub-sections such as Fractal Analysis, Evaluation Metrics used for comparison and flow chart of an improved osteoporosis detection algorithm.

3.1 Fractal Analysis: The fractal geometry was first introduced by Mandelbrot and had a great impact in environmental sciences and physics. Fractals provide a mathematical background for the study of irregular and complex shapes which are widespread in nature. The fundamental notion is the self-similarity of objects. A given finite, n-dimensional set is self-similar if it can be obtained as the union of N self copies, downscaled by a factors r. The set is then, characterized by a parameter called the fractal dimension, denoted by D, that links the self-similarity factors by the equation [16]:

$Nr^{D}=1$ (1)

3.2 Evaluation Metrics: Metrics are performance evaluators for any method or algorithm. In this paper, we have considered different metrics of binary classification to measure the performance of proposed ODFA method. Tables 1 and 2 depict initial measures and performance measures of different osteoporosis detection methods/algorithms respectively [17].

Table 1 Initial Measures

No.	Measure	Description
1	Positive (P)	Pixel is in a class of interest.
2	Negative (N)	Pixel is not in a class of interest.
3	True Positive (TP)	The pixel in the ground truth is positive, while method ranks the pixel as positive. **<u>For Example;</u>** TP refers to the pixels that are correctly labelled as osteoporosis by the tested approach compared with the ground truth.
4	True Negative (TN)	The pixel in the ground truth is negative, while method ranks the pixel as negative. **<u>For Example;</u>** TN refers to the pixels that are correctly labelled as healthy tissue by the tested approach.
5	False Positive (FP)	The pixel in the ground truth is negative, while method ranks as positive. **<u>For Example;</u>** FP refers to the pixels wrongly labelled as osteoporosis by the tested approach.
6	False Negative (FN)	The pixel in the ground truth is positive, while method ranks the pixel as negative. **<u>For Example;</u>** FN refers to the pixels wrongly labelled as healthy tissue by the tested approach

Table 2 Metrics used for performance evaluation

No.	Measure	Description
1	Accuracy	Relation between total of hits on the total set of errors and hits. This value is calculated by: (TP + TN)/(TP + FN + FP + TN)
2	Specificity	Percentage of negative samples correctly identified on total negative samples. This value is calculated by: TN/(FP + TN)
3	Sensitivity	The sensitivity of a test is its ability to determine the patient cases correctly. This value is calculated by: TP/(TP + FN)

3.3 Flowchart: Fig. 2 represents the complete flowchart of proposed ODFA method to detect osteoporosis from human X-Ray images. This algorithm accepts an X-Ray image as an input and if it is RGB/24bits then, we have converted into grayscale image. Image may contain noise, improper blurring or out of focus that is why we have pre-processed it. We have applied 2D Gaussian filter to blur X-Ray image and remove detail and noise. Gaussian filter is similar to the mean filter which is used to remove both types noises Gaussian and salt & pepper. It helps to detect false edges due to noise. As per paper [18] the Gaussian filter is depends on two principles. First, the joint conditional predictive state is assumed to be a Gaussian Probability Distribution Function for linear structure and second, for nonlinear functions there should be models to be approximated. The formula for 2D Gaussian filter is given below [19].

$$G(X,Y) = \frac{1}{2\pi\sigma^2} . e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (2)$$

Where, x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution.

In the next stage, edge detection is performed based on range using 3*3 matrixes starting from top left to bottom right. Segmentation is performed on edged images based on adaptive thresholding classification algorithm. As per above section 3.1 fractal analysis is performed. Fractal analysis result image matrix is compared with trained matrix or images available and finally, thresholding and image optimization is performed to display final output image with osteoporosis detection.

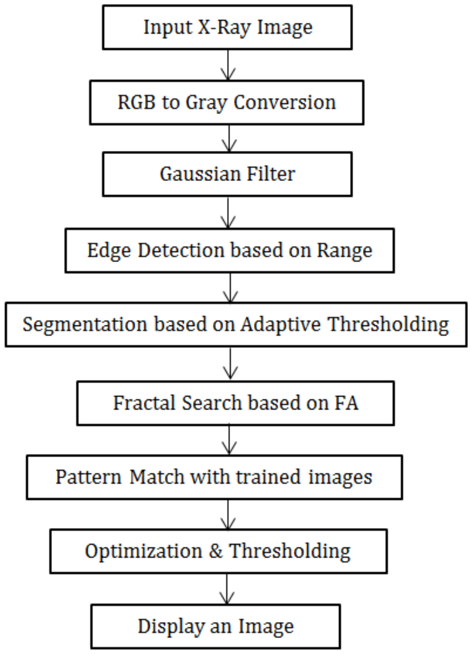


Fig. 2: Flowchart of the proposed ODFA method to detect osteoporosis.

We have compared our proposed ODFA method with three latest methods/algorithms such as Texture Based Method[5], Shape Based Features [6] and Special DIP algorithm [9]. We have considered Accuracy, Specificity and Precision as performance analysis parameters. We have shown that our method is superior.

IV. Algorithm of Proposed ODFA method for Osteoporosis detection

An algorithm is a sophisticated series of steps to be processed to arrive at a particular decision for solution of a problem. We have devised an algorithm in following steps to detect osteoporosis from human arm X-Ray images.

Algorithm: Osteoporosis detection from X-Ray image human arm.

Step-1 : Input an Image.
Step-2 : Perform rgb2gray to convert it in gray scale
Step-3 : Gaussian filter.
Step-4 : Edge Detection based on Range
Step-5 : Segmentation based on Adaptive Thresholding Classification
Step-6 : Search for fractal/pattern of osteoporosis.
Step-7 : Match searched texture with trained images.
Step-8 : Optimization & Thresholding.
Step-9 : Display an image as output.

In **step-1** X-Ray image of human arm is inputted by the user**. Step-2** converts an RGB X-Ray image into gray scale image. **Step-3** does Gaussian filter to remove noise and improper blurring. **Step-4** detects edges from inputted image based on range. If pixel value is between 0 and 10 then, set pixel value 0 for that pixel (mark as Black, It means background part). In **Step-5** We have done segmentation of an inputted X-Ray image based on Adaptive Thresholding Classification algorithm. **Step-6** does the task of pattern or fractal finding. **Step-7** compares the searched fractal/pattern from inputted image with the available pattern in the pre-loaded matrix. **Step-8** we have performed optimization and thresholding operations of the output achieved in step-7 to do labeling of osteoporosis pixel and normal pixel. Finally, **Step-9** displays the output image with detection of osteoporosis.

We have represented above algorithm in pseudo-code as follows. This can be very easy for programmer to convert this pseudocode into real program for osteoporosis detection from human X-Ray image using proposed ODFA algorithm.

Pseudocode: Osteoporosis detection from human X-Ray image

```
READ an X-Ray image
CONVERT an inputted image into gray scale image
DO Gaussian filter on gray scale image
EDGE detection based on statistical range
SEGMENTATION based on adaptive thresholding classification
SEARCH fractal/pattern from available matrix
DETERMINE threshold value
DO comparison between searched pattern and X-Ray image pattern based on decided threshold value
STORE result of comparison in output matrix
CONVERT output matrix into uint8 data type
DISPLAY converted modified image as an output of osteoporosis detection
```

V. Experimental Result and Discussion

This section presents the osteoporosis detection experiments using proposed ODFA method and comparative evaluation of different methods/algorithms. To evaluate the performance of the proposed ODFA algorithm, experiments have been conducted and the results were compared with three latest osteoporosis detection methods. The experiments were evaluated on 10 osteoporosis X-Ray images and 5 normal X-Ray images. Fig. 3 shows original X-Ray images and X-Ray images after osteoporosis detection to illustrate the effectiveness of proposed ODFA method. Test images were collected from hospital in person, downloaded from google images, NHA and imageprocessingplace.com. Table – 3 shows computer system environment on which proposed ODFA method has been evaluated.

Table 3 Environment of Machine.

Environment of Machine	
Operating System	Windows 7 SP 1 (64 bit)
Image Processing S/W.	Scilab 5.5.2
X-Ray Image Detail	512 * 512, 8 bit grayscale, .jpg
Processor	Intel Core i5 1.70 GHz
RAM	4 GB
HDD Capacity	500 GB

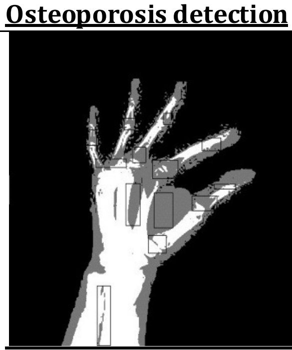
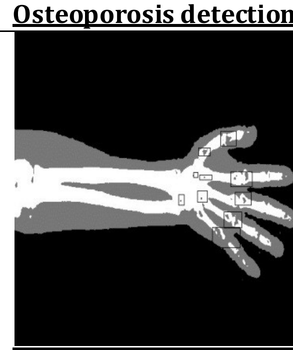
Original Image	**Osteoporosis detection**	**Original Image**	**Osteoporosis detection**
			

Fig.3: Osteoporosis detection from X-Ray images of human arm.

Above figure – 3 shows 2 images as original human arm X-Ray images, and other 2 images with osteoporosis detection using proposed ODFA algorithm. Osteoporosis is highlighted with black regular pattern. Generally it is available as a pattern on the human bones.

Table – 4 Comparison of osteoporosis detection performance of different methods

No.	Method Name	Average (%)		
		Accuracy	**Specificity**	**Sensitivity**
1	Texture Based Method[5]	95.24	85.71	95.20
2	Shape Based Features [6]	73.33	72.23	72.23
3	Special DIP algorithm [9]	86.70	97.50	68.10
4	**Proposed ODFA Method**	**96.27**	**98.09**	**87.05**

Above Table – 4 presents the performance of different osteoporosis detection methods/techniques in terms of Accuracy, Specificity and Sensitivity. It is cleared that our proposed ODFA algorithm achieved accuracy of 96.27% which is greater than 95.24%, 73.33% and 86.70% accuracy of Texture Based Method, Shape Based Features and Special DIP algorithm respectively. The accuracy of proposed ODFA algorithm is increased by 1.03%, 22.94%, 9.57% as compared to Texture Based Method, Shape Based Features and Special DIP algorithm respectively.
The specificity of proposed ODFA algorithm is increased by 12.38%, 25.86%, 0.59% as compared to Texture Based Method, Shape Based Features and Special DIP algorithm respectively. The Sensitivity of proposed ODFA algorithm is increased by 14.82% and 18.95% as compared to Shape Based Features and Special DIP algorithm respectively. While, sensitivity of Texture Based Method is 95.20%, it is higher than proposed ODFA algorithm.
As per above interpretation derived from table – 4, it is cleared that our proposed ODFA algorithm detects osteoporosis very efficiently and effectively as compared to Texture Based Method, Shape Based Features and Special DIP algorithm in terms of Accuracy, Specificity and Sensitivity.

VI. Conclusion and Future Attempts

In this paper, we have presented an improved method for osteoporosis detection from human's arm X-Ray images based on Gaussian filter, range, and adaptive thresholding classification technique and fractal analysis. This algorithm is used to detect osteoporosis from X-Ray images very effectively and efficiently. We have considered Accuracy, Specificity and Sensitivity as performance evaluation metrics. We have also compared results of our method with three latest methods/algorithms. According to above Table – 4, proposed ODFA method achieved average results of 96.27% (accuracy), 98.09% (specificity) and 87.05% (Sensitivity). It is cleared from Fig.3 and table – 4 that proposed ODFA method detects osteoporosis much better as compared to three latest methods such as Texture Based Method, Shape Based Features and Special DIP algorithm. The proposed ODFA method can be used in medical field to develop CADD or DSS based on human X-Ray images or other types of digital images. Researcher can add more features, comparisons and parameters to further evolve and analyse proposed ODFA method.

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