Vertebra osteoporosis detection based on bone density using Index-Singh statistical blended method

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ABSTRACT

Osteoporosis is a progressive decrease in bone density so that the bones become brittle and broken. Bones are composed of minerals such as calcium and phosphate, so the bones become hard and solid. Many people do not realize that osteoporosis is a silent disease. Therefore, early detection of osteoporosis is very important. Detection of osteoporosis can be done by utilizing x-ray images of the vertebra. In this research the detection of bone density using blended statistical methods and Index-Singh. The x-ray sample used in this research was 50 images of osteoporosis patients. The result of the area calculation yields the highest white pixel is 7,983 pixels and the lowest white pixel is 5,410 pixels. Based on the results of these calculations, a statistical grouping is conducted into 6 Index-Singh. The range of statistical values is 5,410–6,266 pixels grouped into Index-Singh 1, range of data 6,323–6,512 pixels grouped into Index-Singh 2, the data range 6,520-6,747 pixels grouped into Index-Singh 3, data range 6,778-6,998 pixels grouped into Index-Singh 4, data range 7,001-7,219 pixels grouped into Index-Singh 5, and data range 7,338-7,983 pixels grouped into Index-Singh 6. Overall, the results of testing the osteoporosis detection system have been successful and can be used as an early detection system for osteoporosis. This assistance system has a detection accuracy of 76% compared to doctor's justification.

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1. INTRODUCTION

Osteoporosis is a common disease characterised by a systemic impairment of bone mass and microarchitecture that results in fragility fractures [1, 2]. Bone is the most important element in the human body as a material of body forming and strengthening. In book [3] and article [4], bone quality is a manifestation of architecture (bone geometry, micro architecture, cortical thickness, and trabecullar connectivity), matrix, and mineralization. Measurement BMD is the principal method of diagnosis of osteoporosis because patients with low BMD values have elevated risk of developing a bone fracture [5]. Osteoporosis is characterized by an absolute decrease in the amount of bone to a level below that required for mechanical support of normal activity and by the occurrence of non-traumatic skeletal fracture [6, 7]. Pharmacologic agents that influence bone remodeling are an essential component of osteoporosis management. Because many patients are first diagnosed with osteoporosis when presenting with a fragility fracture, it is critical to understand how osteoporotic medications influence fracture healing [8]. This situation is high risk because the bones become fragile and easily cracked and even broken. Many people do not realize that osteoporosis is a silent diseases. According to the world health organization (WHO) states to date about 200 million people suffer from osteoporosis and the rest of the world and will multiply in number in subsequent years.

According to the Indonesian Ministry of Health (2015) [9], the impact of osteoporosis in Indonesia in 2006 was already at an alarming rate, reaching 19.7% of the population and continuing to increase with the increasing number of elderly people in the following years. The Ministry of Health states that two out of five people in Indonesia are at risk of developing osteoporosis. International osteoporosis foundation also states that one in three women and one in five men are at risk for osteoporosis. In Indonesian women, the risk of osteoporosis is 23% at 50-80 years and will increase to 53% by the age of 70-80 years, this data showed high level when compared to other Asian countries [10]. Although changes in the bone mass and calcium metabolism are evident in the premenopausal period, menopause marks the beginning of a bone loss that continues until the end of life and is the main cause of osteoporotic fractures in elderly women [11]. Oestrogen treatment improved the calcium balance in these women and arrested their height loss. These findings were the basis for defining postmenopausal osteoporosis and established the link between osteoporosis and vertebral fractures. Several subsequent studies have demonstrated that vertebra fractures represent impaired bone quality and structural decay of the bone. Vertebra fractures reflect the severity of osteoporosis and are strong predictors of future fractures, thus serving as the hallmark of the disease [12]. Improved healthcare, socio-economic and lifestyle changes have led to a dramatically increased life expectancy in modern societies during the past century [12]. To suppress the growth rate of osteoporosis sufferers, we need early information about the condition of bone density that we have. This will provide a faster response to us to maintain our diet and at the same time increase the intake of bone nutrition that our body needs so that our bones do not become brittle quickly. The early diagnosis of osteoporosis is crucial to mitigate the social and economic burden due to ensuing osteoporotic fractures [13, 14].

Initial information on osteoporosis can be known through bone density, but bone mineral density does not explain everything [15]. Bone densities of all regions of the hip were strongly related to the risk of hip fracture [14]. However, samples to make the osteoporosis diagnosis aid system easy to obtain. In addition to bone densitometry, diagnostic tools that are based on osteoporotic fracture risk factors such as FRAX are inexpensive and easy means to identify a large portion of the population for proper treatment. Referring to the description, measurement of bone mineral density (BMD) by DEXA scanning is the basis for the management of osteoporosis [13, 16]. Before the 1994 world health organization (WHO) classification of "normal" versus "osteopenia" versus "osteoporosis" based on bone mineral density (BMD) values (T-scores), the diagnosis of osteoporosis still was made on the basis of low-trauma fractures [17, 18]. In another study [6], the Singh's index (SI) is an inexpensive simple method of assessing bone density at a site where fractures occur. The SI has been criticized for its low reliability due to the subjective nature of its will defined grading for osteoporosis.

Based on the description above, this research using blended singh index with statistical methods. This is to improve the reliability of osteoporosis-assisted diangnosis systems using X-ray scanning. Early diagnosis of osteoporosis uses quantification of digital x-ray data. This research uses image processing algorithms according to publication [19, 20], hat could generate sharper and clearer images or improve the quality of information contained in the image so that it can be visually interpreted better, i.e image enhancement, two-dimensional convolution, alignment and sharpening of images, and edge detection. State of the art this research is using blended method between statistical with Index-Singh from vertebra bone density. This auxiliary system is cheap, easy and high accuracy.

2. RESEARCH METHOD

In this research, the input image is a x-ray osteoporosis image of the spinal vertebra patients obtained from x-ray plane device under the brand name Shimadzu RADSPEED. Type captured image in the spinal cord (spinal vertebra) produces image files in the format of the joint photographic group (JPG) with a resolution of 624x762 pixels. X-ray images used from the Soeharso Orthopedic Hospital in Surakarta have been validated by specialist doctors. X-rays image were obtained as many as 50 samples each with justification of specialist doctors, i.e, osteoporosis, osteopenia, and normal. Flowchart of the research process shown in Figure 1. The first stage in this research is cropping image. Methods and systems are provided for cropping a digital image based on movement data [21]. This cropping process is carried out on x-ray images with a resolution of 624x762 pixels to 126x234 pixels. Cropping is done on the region of interest (ROI) image of the bone alone by trimming the edges of the x-ray image. Cropping is done to clarify the spinal vertebra image object that will be processed i.e, only focuses on the specified object. This is to simplify analysis and storage size of the image. The next process is to resize the image of the crop. This process is carried out to change the x-ray image resolution to 127x127 pixels, so that the dimensions of the x-ray image are the same between horizontal and vertical. In publication [22], changing image size is intended to reduce the workload of the computer so the computation can be done more quickly.

The next stage is a preliminary process (pre-processing). The performed to obtain a good image quality [23] as well as obtain the results of white and black pixels from x-ray images of the spinal vertebra. This section is done so that the desired object can be obtained with maximum results. The resized x-ray image data is then converted into a gray image. After going through the grayscale pre-processing, the x-ray image goes into the next stage by setting the thresholding value in order to determine the black and white level in the image, this stage is called binary image. The purpose of this process is find out the object results from the number of pixels x-ray image of the spinal bone vertebra that exists on a wide area. Publication [22] shows the equation used to determine the area that is calculated using the following equation:

$$Area = \sum_{i=1}^{n}\sum_{j=1}^{m} f(i,j) \quad (1)$$

where n is row, m is *column,* f (i, j) = 1 if (i, j) is an object pixel.

After calculating the area, then proceed to calculate bone density. Bone mineral density is an important parameter to indicate the condition of the bone on any site of the body [24]. This stage is used to determine the density of bone x-ray images. Bone density is calculated by multiplying pixel columns and rows of spinal vertebra x-ray images. The results of the manual calculation, must be the same as the sum of white and black pixels from the results of the process of calculating the area. This pixel calculation will be a reference input data into the next method. Manual calculation of bone density and total pixel area using the following (2) and (3):

$$Tp = nxm \quad (2)$$

where Tp is total pixel, n is row and m is *column.*

$$Tp = \sum i + \sum j \quad (3)$$

where Tp is total pixel, i is white pixel and j is *black pixel.*

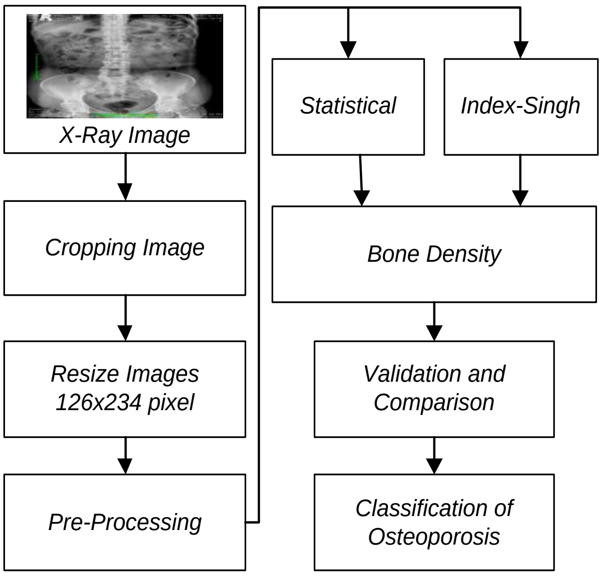


Figure 1. Flowchart of the research process

The next stage is a statistical calculation for Index-Singh classification. The Singh index is a simple, cheap method for giving a rough measurement of bone mass that may still be used to classify osteoporosis grade in countries where access to dual energy x-ray absorptiometry (DEXA) scanning is limited [25].

Although Singh's index has a low sensitivity, it is specific in diagnosing low bone mass, suggesting its suitability for use in classifying large populations, but not individuals with osteoporosis [26]. This method is the stage of collecting quantitative data results from the calculation of bone density on the x-ray image of the spinal vertebra. In this method the result of the amount of existing data sorted one by one into a table that only consists of the number of white pixels only from the largest to the smallest. Index-Singh has levels from 1-6. This method is used as a grouping of each pixel result into grade or bone classification from normal to osteoporosis. From the method that has been done is to combine between Statistical and Index-Singh, then blended Statistical Index-Singh aims to increase the value of accuracy. Grouping according to Index-Singh of each pixel from normal level bone classification to osteoporosis using the following equation:

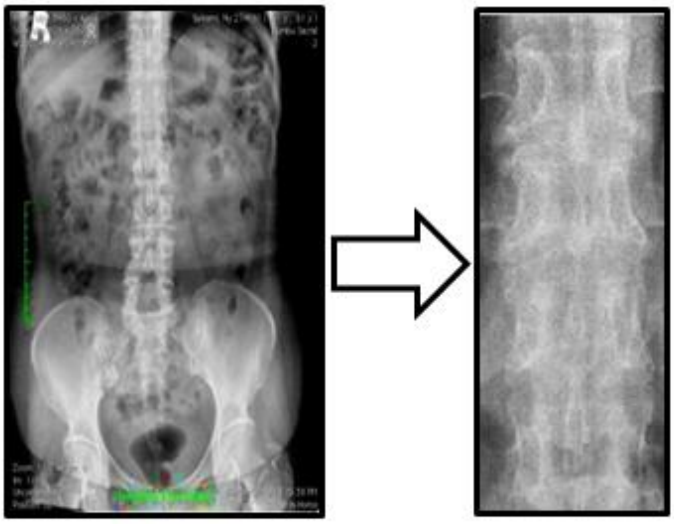
$$G_{is} = \frac{\sum S}{\sum G} \quad (4)$$

$$\mathrm{P_{wp}} = \frac{\mathrm{W_p}}{\mathrm{W_p} + \mathrm{B_p}} \times 100\% \quad (5)$$

where $\mathrm{P_{wp}}$ is percentage of white pixels, $\mathrm{W_p}$ is white pixels dan $\mathrm{B_p}$ is black pixels.

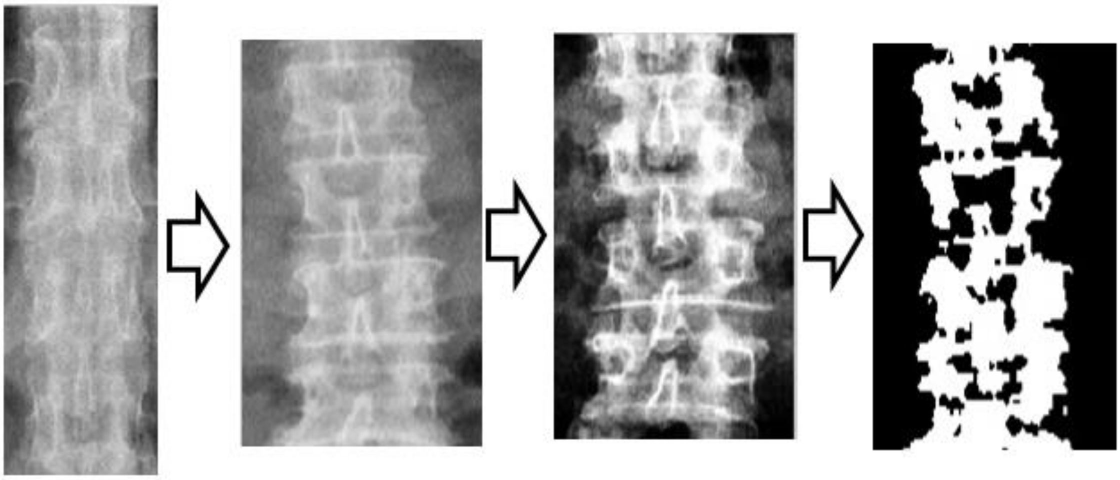
3. RESULTS AND ANALYSIS

The first stage in this research is cropping image as shown in Figures 2 (a) and 2 (b). Figure 2 (a) is an original image from Soeharso Orthopedic Hospital in Surakarta and Figure 2 (b) is result cropping. The original x-ray image with a resolution of 624x762 pixels, while the results of its cropping are 126x234 pixels. After that the resizing of the cropping image resumes. Results are shown in Figure 3 (a). After obtaining the results, continue the conversion of x-ray images to gray images. Result of this process shown in Figure 3 (b). The next process is histogram leveling, for mapping the grayscale of the spinal vertebra's x-ray image. After that, continue the process of clahe and median filter. This research same with article [27] uses the median filtering to do image preprocessing. The purpose of this process is to increase the contrast in the image, so that the bone structure in the spinal vertebra is seen more clearly. The results of this process are shown in Figure 3 (c). The final process in pre-processing is binaryization of x-ray images. The purpose of this process is to identify the existence of objects using thresholding, where the object will be logic 1, and background logic 0. Logic 1 is white, logic 0 is black. The results of this process are shown in Figure 3 (d).



(a) (b)

Figure 2. (a) Original image, (b) Cropping result



(a) (b) (c) (d)

Figure 3. (a) Cropping result, (b) Resize and gray image, (c) Clahe and median filter, (d) Binary image

After obtaining the results, continue the next stage is a statistical calculation for index-Singh classification. Result of statistical Index-Singh of 50 data stamps of the largest white pixel x-ray images is 7,983 pixels and the smallest white pixel is 5,410 pixels. The results of each value of white pixels are grouped into six parts of Index-Singh of grade 1 to grade 6, respectively. The result of the statistical Index-Singh process shown in Table 1. White pixels in Table 1 can be interpreted to represent the density bone of spinal vertebra. The number of white pixels to Singh Index can be grouped into grades 1 through grade 6. The total number of white pixels against Singh Index is shown in Table 2. Overall in each group of Index-Singh 1 to Index-Singh 6 it was seen that in each group the number of each subject of the most common white pixel data in the group was in the category of osteoporosis. Overall pixel whiteness in each group is in the category of osteopenia and normal.

Table 1. Result of statistical and Index-Singh

No	White Pixel	Black Pixel	% White Pixel	Index-Singh	No	White Pixel	Black Pixel	% White Pixel	Index-Singh
1	6,266	9,864	38.85%		1	6,998	9,132	43.38%	
2	6,215	9,915	38.53%		2	6,980	9,150	43.27%	
3	6,153	9,977	38.15%		3	6,976	9,154	43.25%	
4	6,151	9,979	38.13%		4	6,964	9,166	43.17%	4
5	6,109	10,021	37.87%	1	5	6,893	9,237	42.73%	
6	6,083	10,047	37.71%		6	6,850	9,280	42.47%	
7	6,001	10,129	37.20%		7	6,794	9,336	42.12%	
8	5,966	10,164	36.99%		8	6,778	9,352	42.02%	
9	5,921	10,209	36.71%		1	7,219	8,911	44.76%	
10	5,410	10,720	33.54%		2	7,192	8,938	44.59%	
1	6,512	9,618	40.37%		3	7,103	9,027	44.04%	
2	6,492	9,638	40.25%		4	7,082	9,048	43.91%	
3	6,477	9,653	40.15%		5	7,059	9,071	43.76%	5
4	6,444	9,686	39.95%		6	7,028	9,102	43.57%	
5	6,421	9,709	39.81%	2	7	7,016	9,114	43.50%	
6	6,379	9,751	39.55%		8	7,001	9,129	43.40%	
7	6,356	9,774	39.40%						
8	6,323	9,807	39.20%						
					1	7,983	8,147	49.49%	
1	6,747	9,383	41.83%		2	7,862	8,268	48.74%	
2	6,711	9,419	41.61%		3	7,620	8,510	47.24%	
3	6,708	9,422	41.59%		4	7,571	8,559	46.94%	
4	6,645	9,485	41.20%	3	5	7,487	8,643	46.42%	6
5	6,630	9,500	41.10%		6	7,426	8,704	46.04%	
6	6,544	9,586	40.57%		7	7,339	8,791	45.50%	
7	6,543	9,587	40.56%		8	7,338	8,792	45.49%	
8	6,520	9,610	40.42%						

Table 2. Number of white pixels against Index-Singh

No	Index-Singh 1	Index-Singh 2	Index-Singh 3	Index-Singh 4	Index-Singh 5	Index-Singh 6
1	6,266	6,512	6,747	6,998	7,219	7,983
2	6,215	6,492	6,711	6,980	7,192	7,862
3	6,153	6,477	6,708	6,976	7,103	7,620
4	6,151	6,444	6,645	6,964	7,082	7,571
5	6,109	6,421	6,630	6,893	7,059	7,487
6	6,083	6,379	6,544	6,850	7,028	7,426
7	6,001	6,356	6,543	6,794	7,016	7,339
8	5,966	6,323	6,520	6,778	7,001	7,338
9	5,921	-	-	-	-	-
10	5,410	-	-	-	-	-

The percentage value of each white pixel of x-ray image of the spinal vertebra is shown in Table 3. That ranges from 33.54-38.85% indicates that the value is a group of Index-Singh 1 in the category of osteoporosis group. Bone density is reduced, which makes bones porous and brittle and they break easily. In Index-Singh 2, Index-Singh 3, Index-Singh 4, and Index-Singh 5 with percentage of range value from 39.20-44.76% belong to category of osteopenia group. Osteopenia category is when your bones are weaker than normal but not so far gone that they break easily, which is the hallmark of osteoporosis. Percentage value with range 45.49-49.49% average value in group included in Index-Singh 6 with normal category.

Table 3. Percentage value against Index-Singh

No	Index-Singh 1	Index-Singh 2	Index-Singh 3	Index-Singh 4	Index-Singh 5	Index-Singh 6
1	38.85%	40.37%	41.83%	43.38%	44.76%	49.49%
2	38.53%	40.25%	41.61%	43.27%	44.59%	48.74%
3	38.15%	40.15%	41.59%	43.25%	44.04%	47.24%
4	38.13%	39.95%	41.20%	43.17%	43.91%	46.94%
5	37.87%	39.81%	41.10%	42.73%	43.76%	46.42%
6	37.71%	39.55%	40.57%	42.47%	43.57%	46.04%
7	37.20%	39.40%	40.56%	42.12%	43.50%	45.50%
8	36.99%	39.20%	40.42%	42.02%	43.40%	45.49%
9	36.71%	-	-	-	-	-
10	33.54%	-	-	-	-	-

Testing with 50 data samples is shown in Table 4. Comparison between orthopedist validated data with test system data there are similarities of 38 samples with osteoporosis, osteopenia, and normal justification categories. In addition, there are differences between orthopedist validation data and system test data of 12 samples, because result of sample from system data test is not same with the validation results of image data justification which is parameter of success test of a system. The percentage accuracy of the system test data with the doctor validation data is obtained by the following equation:

$$A = \frac{TTR}{NTD}\, x\, 100\%$$

$$A = \frac{38}{50}\, \mathrm{x}\, 100\%$$
$$= 76\,\%$$

So, the end result of this osteoporosis detection aids system has an accuracy of 76% and a system error of 24%. In the process of calculating the accuracy that has been obtained, which is taken from the result of the same test data sample x-ray image divided by the total number of x-ray image data test of 50 samples. The whole sample has been processed into the image processing and using the calculation of the area on x-ray images of the spinal vertebra that results in the number of white pixels and black pixels. Overall the percentage of white pixel values against singh index from grade 1 to grade 6 can determine the classification of osteoporsis, osteopenia, and normal bone. This process uses a setup value that is calculated through a range of average values, so that an average value of less than 39.20% is osteoprosis bone and if the average value exceeds 44.76% then the bone is normal and the average value middle range between 39.20-44.76% then osteopenia.

Table 4. Comparative table validation and system test

No	% White pixel	Justification of data from orthopedist	System test data	System test results
1	38.85%	Osteoporosis	Osteoporosis	True
2	42.12%	Osteopenia	Osteopenia	True
3	43.27%	Osteopenia	Osteopenia	True
4	40.42%	Osteopenia	Osteopenia	True
5	37.71%	Osteoporosis	Osteoporosis	True
6	43.76%	Osteopenia	Osteopenia	True
7	39.95%	Osteopenia	Osteopenia	True
8	45.49%	Normal	Normal	True
9	41.20%	Osteopenia	Osteopenia	True
10	36.71%	Osteoporosis	Osteoporosis	True
11	43.50%	Osteopenia	Osteopenia	True
12	46.94%	Osteoporosis	Normal	False
13	47.24%	Osteoporosis	Normal	False
14	41.83%	Osteopenia	Osteopenia	True
15	46.42%	Osteoporosis	Normal	False
16	40.25%	Osteopenia	Osteopenia	True
17	43.57%	Osteopenia	Osteopenia	True
18	44.59%	Osteopenia	Osteopenia	True
19	37.20%	Normal	Osteoporosis	False
20	43.38%	Osteopenia	Osteopenia	True
21	41.10%	Osteopenia	Osteopenia	True
22	45.50%	Osteoporosis	Normal	False
23	40.56%	Normal	Osteopenia	False
24	39.40%	Osteopenia	Osteopenia	True
25	37.87%	Osteoporosis	Osteoporosis	True
26	39.55%	Osteopenia	Osteopenia	True
27	49.49%	Osteopenia	Normal	False
28	43.91%	Osteopenia	Osteopenia	True
29	43.17%	Osteopenia	Osteopenia	True
30	42.47%	Osteopenia	Osteopenia	True
31	38.13%	Osteoporosis	Osteoporosis	True
32	41.61%	Osteopenia	Osteopenia	True
33	44.04%	Osteopenia	Osteopenia	True
34	39.81%	Osteopenia	Osteopenia	True
35	44.76%	Osteopenia	Osteopenia	True
36	48.74%	Osteoporosis	Normal	False
37	42.02%	Osteopenia	Osteopenia	True
38	33.54%	Osteoporosis	Osteoporosis	True
39	36.99%	Osteoporosis	Osteoporosis	True
40	43.25%	Osteopenia	Osteopenia	True
41	46.04%	Osteoporosis	Normal	False
42	38.53%	Osteopenia	Osteoporosis	False
43	41.59%	Osteopenia	Osteopenia	True
44	40.37%	Osteopenia	Osteopenia	True
45	38.15%	Osteopenia	Osteoporosis	False
46	40.15%	Osteopenia	Osteopenia	True
47	43.40%	Osteopenia	Osteopenia	True
48	40.57%	Osteopenia	Osteopenia	True
49	39.20%	Osteopenia	Osteopenia	True
50	42.73%	Osteoporosis	Osteopenia	False

4. CONCLUSION

This reseach was successfuly developed the veterba osteoporosis detection based on bone density using Index-Singh statistical blended method. The statistical Index-Singh blended method on x-ray images of the spinal vertebra can be used for sorting and classifying white pixels in osteoporosis-level detection. The result of the number of white pixels in the calculations based on the area of columns and rows of the area is the amount or density of the bone mass of the spinal vertebra. In other words, bone density is represented by the number of white pixels of an area. Overall, the results of testing the osteoporosis detection system have been successful and can be used as an early detection system for osteoporosis. This assistance system has a detection accuracy of 76% compared to doctor's justification. The accuracy of osteoporosis detection system this research needs to be improved by increasing the sample and the quality of pre-processing.

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