# Support Vector Machine Multiclass using Polynomial Kernel for Osteoporosis Detection

Deasy Alfiah Adyanti[1], Dian C. R. Novitasari[1], and Aris Fanani[1]

*[1]Department of Mathematics, UIN Sunan Ampel Surabaya, Ahmad Yani, Surabaya, Indonesia*

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Abstract:     Support Vector Machine is a good performance machine learning algorithm applied as a classification method. In SVM, several problems are difficult to be separated linearly, for mapping data from the lower dimensional to the higher dimensional space, the kernel method is needed. The purpose of this research is to classify data into normal bone, osteopenia, and osteoporosis using SVM Multiclass with polynomial kernel parameters. The classification is based on the analysis of the mandibular ramus bone observed from changes in the trabecular pattern of the jaw bone and hip fracture using SVM Multiclass. Before using SVM multiclass, an image enhancement was performed with adaptive histogram equalization, and feature extraction with the gray level co-occurrence matrix (GLCM). The variable input used in this research is dental panoramic radiograph data as much as 61 data divided into two parts that are 75:25 as training and as test data. Based on the implementation of SVM Multiclass with the polynomial kernel as the basis of computer-aided diagnosis system for osteoporosis detection, the best test data accuracy is 81.25%.

## 1 INTRODUCTION

One of the machine learning algorithms that many are developed and applied for the classification problem is the SVM method. This method gives better results than the other (Prasetyo, 2014). The maximizing hyperplane is the idea of SVM classification. SVM has a field that separates into two class, they are positive class and negative class, so SVM just classifies two classes or binary classification. But, in the SVM several data can't be linearly separated by a separating hyperplane though plus slack variable (Shastry, et al., 2017). So, the SVM needs kernel method to be applied to data non-linearly (Prasetyo, 2014). The basis of the kernel is the mapping of data from low dimensional to high dimension space (Feng & Liao, 2017).

Several problems have implemented SVM for linear and nonlinear classification problems, one of which is the classification of bone disease. Like Muthu Subash Kavitha's research who implements Fractal Dimension (FD) and GLCM for texture analysis on the mandibular bone using panoramic radiographic images for diagnosis of Korean female osteoporosis (Kavitha, et al., 2014), the method of

classification used on the research are SVM, KNN, and Naive Bayes Classifier.

Another study was also conducted by Suprijanto which analysis panoramic radiographic images on the mandibular bone for osteoporosis detection with the GLCM method. In the research, the classification method used is SVM for normal bone and osteoporosis classification (Suprijanto, et al., 2013) (Azhari, et al., 2014).

Based on these researches, alternative osteoporosis detection is analysis the texture of the mandibular bone using dental panoramic radiograph (DPR) image which is classified using SVM. Implementation of methods is very useful because of osteoporosis is a type of silent disease and progressive. The symptoms of the disease cannot be known until the fracture. Consequences of the disease are fractures, bone defects, complications, until death (Ramkumar & Malathi, 2016). There radiological examination of osteoporosis using DEXA cannot be used as a good alternative to detection osteoporosis. Inspection using tools such as DEXA requires a relatively high cost and the tools are limited (Ramkumar & Malathi, 2016).

In this research, texture analysis uses GLCM for feature extraction and the method of classification uses SVM Multiclass. SVM Multiclass implemented

to be able to classify bones into three categories directly. They are normal, osteopenia and osteoporosis. The expectation from this system can classify bone based on grey level characteristics into three categories and the result of this system is suitable for early detection of osteoporosis.

## 2 LITERATURE REVIEWS

### 2.1 SVM Multiclass

The SVM method just for the problem of two classes, so to the multiclass problem there are three approaches. In this research use the ECOC approach. It is one of SVM Multiclass method inspired by theoretical information to send messages through the channel (Kikuchi & Abe, 2005).

The idea of this approach is adding the data redundant into the message like code word. So, the recipient can detect errors in messages and can recover the original message if there are several minor errors (Prasetyo, 2014).

### 2.2 Kernel

The kernel is a method applied to non-linearly separate data. The basis of the kernel is mapping the data into higher dimensions space using functions $\theta(x)$, with the multiplication of its function is (Shastry, et al., 2017):

$$\left( \theta(x_i) . \theta(x_j) \right) = K\left(x_i, x_j\right) \qquad (1)$$

Some basis kernels have been used in SVM, such as linear kernel, radial basic function, quadratic and polynomial kernel. Each of these kernels used in experiments to determine kernel and kernel parameters that it can provide the best accuracy in classification.

Using the mapping function $\theta(x)$, every form multiplication $x_i . x_j$ will be calculated $K(x_i, x_j)$. Next $x_i{}'$ mapped to space with higher dimensions. This research, polynomial kernel used for SVM Multiclass classification. Equation 2 is the polynomial kernel equation.

$$Polynomial = K\left(x_i, x_j\right) = \left(x_i . x_j + 1\right)^p \qquad (2)$$

### 2.3 GLCM

The technique of two-order statistics that apply the concept of relationship neighbor probability between two pixels at a distance and an angle orientation is called as GLCM (Kavitha, et al., 2014). GLCM has four orientation angle with interval $45^0$, they are $0^0, 45^0, 90^0$, dan $135^0$ and distance set by 1 pixel (Suprijanto, et al., 2013). GLCM has some statistical features. On this research features the statistics used are a combination of contrast, correlation, energy, and homogeneity. The combination of these four features it is the best input to bone mineral density (BMD) classification rather than on a combination of other features (Suprijanto, et al., 2013). Below is the definition of features:

#### 2.3.1 Contrast

The size of the grey intensity of an image or the size of the grey element distribution in an image is called as contrast (Hazra & Dutta, 2015). Equation 3 is contrast equation.

$$Contrast = \sum_{i}^{N} \sum_{j}^{N} |i - j|^2 P(i, j) \qquad (3)$$

$N$ = Size of line/column
$i$ = Line
$j$ = Column
$P(i, j)$ = Probability of co-occurrence matrix

#### 2.3.2 Correlation

Correlation shows the size of the linear structure of the grey of an image (Suprijanto, et al., 2013). Equation 4 is the equation of the correlation.

$$Correlation = \sum_{i=1}^{N} \sum_{j=1}^{N} \frac{(i - \mu_i)(j - \mu_i)P(i, j)}{\sigma_i \sigma_j} \qquad (4)$$

With the mean and standard deviation in equation 5 until 8

$$\mu_i = \sum_{i=1}^{N} \sum_{j=1}^{N} i\left(P(i, j)\right) \qquad (5)$$

$$\mu_j = \sum_{i=1}^{N} \sum_{j=1}^{N} j\left(P(i, j)\right) \qquad (6)$$

$$\sigma_i = \sqrt{\sum_{i=1}^{N} \sum_{j=1}^{N} P(i, j)(i - \mu_i)^2} \qquad (7)$$

$$\sigma_j = \sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} P(i,j)(j-\mu_j)^2} \qquad (8)$$

### 2.3.3 Energy

Energy is the size of concentration eligible pixel of co-occurrence matrix intensity on some coordinates (Hazra & Dutta, 2015). Equation 9 is the energy equation.

$$Energy = \sum_{i=1}^{N}\sum_{j=1}^{N} P(i,j)^2 \qquad (9)$$

### 2.3.4 Homogeneity

Homogeneity is the homogeneity of the image that has a similar degree of grey (Suprijanto, et al., 2013). Equation 10 is the equation of homogeneity.

$$Homogeneity = \sum_{i=1}^{N}\sum_{j=1}^{N} \frac{P(i,j)^2}{1+(i-j)^2} \qquad (10)$$

## 2.4 Image Enhancement

Image Enhancement is an enhancement of image on a spatial domain that aims to the process the image so that results are obtained more appropriate than the original image (Gonzalez & Woods, 1997). Processes on the spatial domain can be written in equation 11.

$$g(x,y) = T[f(x,y)] \qquad (11)$$

$f(x,y)$ is the input image, $g(x,y)$ is an output image, and $T$ is an operator $f$, which is defined in the neighborhood of $(x,y)$ (Gonzalez & Woods, 1997). While AHE is a development of the histogram equalization method aims for obtain a uniform spread of histogram. So, every degree of gray image of the DPR image has the number of uniform pixels (Anand & Gayathri, 2015).

## 2.5 Osteoporosis

Osteoporosis is one type of disease chronicles characterized by low mass bone, damage bone structure and tissue accompanied by bone architectural microstructure with decreased quality of bone tissue. This disease can lead to bone fragility, which is resulting in easy bone cracking, or broken (Harrar & Hamami, 2012). Before the bone has osteoporosis, the bone will have osteopenia. Osteopenia is a state density (bone density) is less meeting compared to normal bone in general however quite low to be diagnosed as osteoporosis. Figure 1 is micro-architectural images of bone tissue.
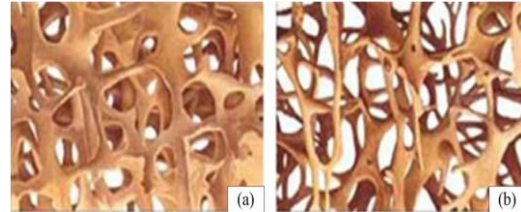


Figure 1: Micro-CT Images of Trabecular Bone, (a) Normal Bone (b) Osteoporosis

## 2.6 Dental Panoramic Radiograph (DPR)

Panoramic radiography is one technique X-rays are used to view the structure of facial teeth and jaw including maxillary bone and the mandible bone and its supporting structure. The type of image is RGB (red, green, blue) (Fanani & Ulinnuha, 2016) that can be used as alternative osteoporosis detection. The DPR image has a relationship between mandibular bone and bone mass density. We can detection of osteoporosis with measure of the width bone of the mandibular cortex and analysis the density trabecular mandibular bone.

# 3 RESEARCH METHODS

## 3.1 Types of Research

Support vector machine using multiclass polynomial kernel for osteoporosis detection including in the type of applied research seen from the aspect of its function. The results of this classification aim as an appropriate and detection alternative accelerate osteoporosis examination.

## 3.2 Data Collection

The data used in this research is the jaw bone data of DPR is focused on the mandibular ramus to determine the BMD. The amount of image data of the DPR used as many as 61 data (24 is normal bone data, 24 is osteopenia, and 13 is osteoporosis). Data

obtained from Clinical Laboratory Pramita Jl. Raya Jemur Andayani 67 Surabaya.

## 3.3 Data Analysis

This research use jaw bones data. The total of data is 61 DPR images (24 is osteopenia, 24 is normal bone, and 13 is osteoporosis). Data is divided into two parts. The first part as 45 training data (18 is osteopenia, 18 is normal bone, and 9 is osteoporosis), and the second part as 16 testing data (6 is osteopenia, 6 is normal bone and 4 is osteoporosis). In achieving the goals in this study, it is necessarily carried out data analysis steps with using three steps. They are image pre-processing, feature extraction using GLCM and classification using SVM Multiclass.

## 3.4 Testing and Evaluation

The first test is done by image pre-processing by taking DPR image which then carried out texture analysis using GLCM to get feature extraction which used as input for SVM Multiclass. Figure 2 is a flowchart of osteoporosis detection.
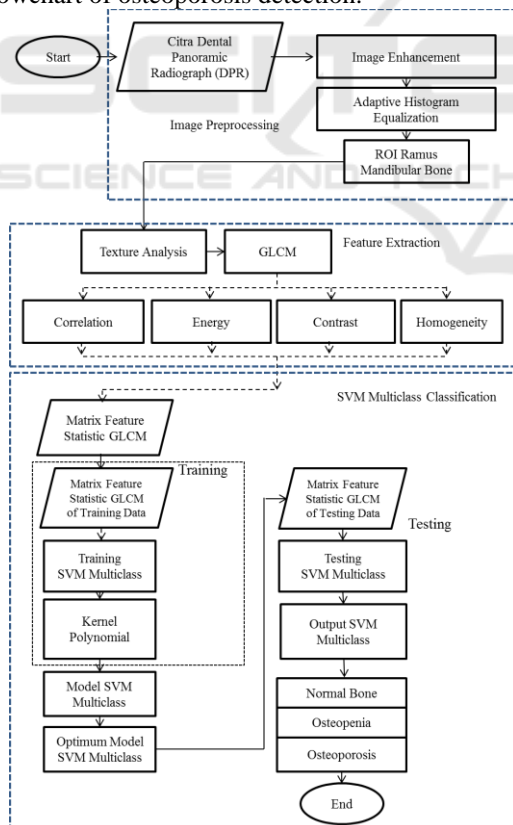


Figure 2: Flowchart SVM Multiclass for Osteoporosis Detection

The steps of osteoporosis detection as follows:

a. The process of image enhancement or ordinary referred to as the pre-processing.
b. The image of DPR is improved using the image enhancement with adaptive histogram equalization methods.
c. After the image is processed by adaptive histogram equalization, then, used ROI process with cropping 80 x 100 pixels on the mandibular bone, in order for the image to be focused on the ramus mandibular bone.
d. The texture analysis is then performed using GLCM to get feature extraction.
e. The results of the GLCM are taken from four features statistics. They are contrast, energy, correlation, and homogeneity.
f. The vector feature matrix derived from the feature statistics contrast, energy, correlation, and homogeneity. Then four feature statistics used as SVM Multiclass input.
g. Division of data obtained from the matrix features vector GLCM, data is divided into training and test data.
h. Selection of kernel (we used polynomial kernel) and SVM parameters, because data is nonlinear data obtained from the matrix of GLCM vector features.
i. The establishment of the SVM Multiclass model
j. After SVM Multiclass model is obtain, the next step is testing phase.
k. After the testing phase is complete, got the optimum model from the best angle orientation of GLCM and best kernel of SVM, next determined results classification.
l. Classification is divided into three categories such as normal bone, osteopenia, and osteoporosis.

## 4 RESULT AND DISCUSSION

Patients with osteoporosis, the number of trabecular will decrease due to the reduction of estrogen hormone that caused occur depletion of trabecular. The containing section many trabecular are mandibular bones. In this research, the mandibular bone ROI was selected is located in the ramus mandibular. This matter because the ramus mandibular bone is the bone which is rough, broad and sharper and often experiencing a bone fracture. Figure 3 is the sample of DPR images.
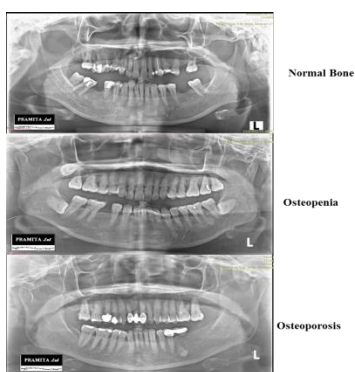
Figure 3: Sample Data of DPR Images

Image processing in this research is done through three steps such as phase of pre-processing data, feature extraction step and classification step. Step of pre-processing done in the form of process grayscale, image enhancement, adaptive histogram equalization, and ROI in the form of cropping on the ramus mandibular bone with the size of 100 x 80 pixels. The following Figure 4 is the result of the improvement image of DPR.
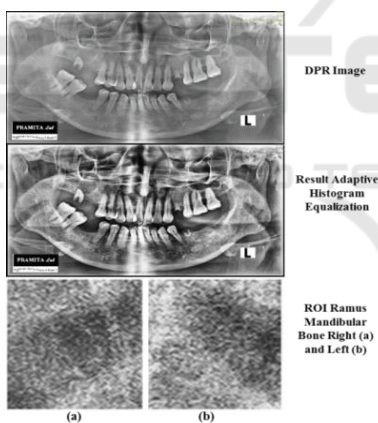


Figure 4: Pre-processing Result

Furthermore, GLCM texture analysis was performed on ROI ramus mandibular bone to get feature statistics from correlation, contrast, energy, and homogeneity. The feature extraction is calculated using Equation 2.3 to Equation 2.10. Using the equation got the value feature extraction with orientation angle $0^0, 45^0, 90^0$ and $135^0$ and with distance $d = 1$ pixels. Result from a single data train in table 4.1.

Table 1: Value of Contrast, Correlation, Energy, and Homogeneity

| $\theta$ | C | Co | E | H |
|---|---|---|---|---|
| 0 | 0.4632 | 0.8861 | 0.0953 | 0.7978 |

| 45 | 0.6281 | 0.8454 | 0.0825 | 0.7557 |
| 90 | 0.4405 | 0.8911 | 0.0967 | 0.8011 |
| 135 | 0.6035 | 0.8515 | 0.0844 | 0.7602 |

With:
$\theta$ = Angle Orientation of GLCM
C = Contrast
Co = Correlation
E = Energy
H = Homogeneity

The problem of osteoporosis detection using SVM classification is a problem multiclass, then this research uses the ECOC method. Long code word which will be used in this research is three bits, as shown in Table 2.

Table 2: Encoding Class to Osteoporosis Detection

| Class | Code word | | |
|---|---|---|---|
| N (1) | 1 | 1 | 1 |
| Os (2) | 0 | 0 | 1 |
| Osteo(3) | 0 | 1 | 0 |

With N is normal bone, Os is osteopenia, an Osteo is osteoporosis. Based on the encoding class in Table 2, then, carried out the construction of the model. The first model is a binary model for separator between {'normal'} with {'osteopenia', 'osteoporosis'}. The second model is separator between {'normal', 'osteoporosis'} with {'osteopenia'}, and the third model is the separator between {'normal', 'osteopenia'} with {'osteoporosis'}. Next, the calculation of Hamming distance to be matched with class nearest.

The steps of the algorithm use the ECOC classification is the same as the algorithm SVM binary classification. By using the kernel polynomial with two degrees, the next step we built SVM model. Each element of the kernel matrix is the result which correlated with $x_i . x_j$ and is a replacement for dot product inequality of duality Lagrange multiplier. After obtained SVM Multiclass model, then used confusion matrix as a measure of classification work for the detection of osteoporosis using four measuring performance are accuracy, sensitivity, specificity, and precision. The equation of accuracy, sensitivity, specificity, and precision is equation 12 to 15.

$$Acuracy = \frac{TP + TN}{TP + FN + FP + TN} \quad (12)$$

$$Sensitivity = \frac{TP}{TP + FN} \quad (13)$$

$$Spesificity = \frac{TN}{FP + TN} \quad (14)$$

$$Precision = \frac{TP}{FP + TP} \quad (15)$$

The testing of osteoporosis diagnose uses Table 3, with TP is the patient has the disease and diagnose is exact, TN is the patient hasn't diseased and diagnose is exact, FP is the patient hasn't diseased and diagnose is wrong, and FN is the patient has the disease and diagnose is wrong.

Table 3: Result of Diagnose

| Real | Prediction | | Sum |
|---|---|---|---|
| | Positive | Negative | |
| Present | TP | FN | TP + FN |
| Absent | F) | TN | FP + TN |

Experiment results with four orientation angles using the kernel polynomials are expressed in Table 4. Then, implementation of SVM Multiclass method with analysis dental panoramic radiograph images on the ROI ramus mandibular used as basic on CADS has been ably used as osteoporosis detection.

Table 4: Value of Confusion Matrix

| Angel | Working Estimator Classification | Training | Testing |
|---|---|---|---|
| $0^0$ | Accuracy | 75,5% | 62,5% |
| | Sensitivity | 72,2% | 55,6% |
| | Specificity | 86,8% | 80% |
| | Precision | 78% | 42% |
| $45^0$ | Accuracy | 66,67% | 81,25% |
| | Sensitivity | 64,8% | 75% |
| | Specificity | 82,7% | 90% |
| | Precision | 64,5% | 88,89% |
| $90^0$ | Accuracy | 68,89% | 81,25% |
| | Sensitivity | 66,67% | 55,56% |
| | Specificity | 83,6% | 80% |
| | Precision | 66,4% | 42,3% |
| $135^0$ | Accuracy | 80% | 81,25% |
| | Sensitivity | 78,2% | 75% |
| | Specificity | 89,2% | 90% |
| | Precision | 81,67% | 88,89% |

Based on Table 4, extraction features GLCM with four features statistics shown the best orientation angle is $135^0$ and distance $d = 1$ pixels. Results show the accuracy of test data generated of 81.25%, sensitivity of 75%, specificity of 90%, and precision of 88.89%.

## 5 CONCLUSIONS

Based on the result of SVM method implementation Multiclass with the polynomial kernel for osteoporosis detection, it can be concluded that SVM Multiclass method with kernel polynomials of two degrees can be used as the basis of CADS for osteoporosis detection. Extraction features GLCM based on a combination of four feature statistics to identify the value bone mineral density from the one analysis the mandibular ramus bone has pointed at the best orientation angle is $135^0$ with distance $d = 1$ pixels. The results show the best test data accuracy is 81.25%, sensitivity is 75%, specificity is 90%, and precision is 88.89%.

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