Osteoarthritis severity using linear vector quantization based first order feature

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Abstract. Many researchers conducted research on osteoarthritis. This is due to the large number of osteoarthritis patients. In Indonesia, one of ten people at risk of osteoarthritis. In addition, osteoarthritis cannot be cured, so it is important to know its status earlier. This study only focuses on the Decision Support System on the knee although osteoarthritis can occur in the hip, spine, thumb, index finger and toe. The severity of osteoarthritis which is divided into 5 clusters, namely KL-Grade 0 to KL-Grade 4. KL-Grade 0 shows normal conditions, and KL-Grade 4 is the worst condition. The purpose of this study is to build a Decision Support System (DSS) to determine osteoarthritis severity using Linear Vector Quantization (LVQ) based on First Order (FO) features. The method used is Linear Vector Quantization (LVQ) based on First Order (FO) features. The experiment was divided into four stages: image processing, feature extraction learning process, and testing process. The results obtained were that the system can classified well for KL-Grade 4 and KL-Grade 3, while for KL-Grade 0, KL-Grade 1, and KL-Grade 3 it still cannot properly qualify according to the cluster.

1. Introduction

Osteoarthritis is an incurable disease, so it is very important to know its status early [1]. It is estimated that there are 9.6% of men and 18.0% of female patients aged over 60 years in the world [2]. Osteoarthritis patients in Indonesia are estimated 30% in 1995 to 2007 [3]. Therefore if the status of osteoarthritis is known, it can be used as a consideration for further treatment. Osteoarthritis status has 5 levels of severity, where normal is stated as KL-Grade 0 and the worst (severe) condition is commonly stated as KL-Grade 5[3].

There have been many studies that discuss the classification of osteoarthritis based on image processing and machine learning [4, 5, 6]. Osteoarthritis severity detection using fisher score resulting that the system can detect grades of low severity, but for high severity further research must be done to get better accuracy [7]. The research which is also based on texture features is using Gray Level Cooccurrence Matrix texture which is then processed using Self Organizing Map (SOM). The results of this study are still difficult to classify for grade 1 and grade 2 severity. This is because these two grades have similarity characteristics that are quite high [8]. Image processing-based research is done by angle-based x-ray image of osteoarthritis [9] and image-based using Gabor kernel [10].

However, the results of these studies still do not have very good accuracy, so this research must be continued by using several appropriate methods. The research that has been done is by using image
processing, followed by learning machines, both Self Organizing Map, Neural Network, and even the end result using the fisher score. While image-based features that have been studied using Gray Level Coocurance Matricies and Run Length Matrix, while there are no first-order feature-based features. Even though the features are based on various methods including the Level of Coaching Insurance, Run Length Matrix, and also first order. Based on this, the study of determining the status of osteoarthritis based on first order is important to investigate.

The aim of this research is conducted to determine the severity of osteoarthritis using Linear Vector Quantization based on first order features. The novelty of this research is that from several studies not yet discussed the first order osteoarthritis detection method. It is expected that using first order based Linear Vector Quantization can improve accuracy in determining the severity of osteoarthritis. It is hoped that this research can contribute to improving or finding a breakthrough method for determining the severity of osteoarthritis.

2. Methodology
2.1. Data
The data used in this research obtained from Osteoarthritis Initiative (OAI) [11]. The data in this study were on x-ray image data of knee osteoarthritis which x-ray image retrieval process used 30 degree angle. Data is divided into learning data and testing data. The amount of learning data used for each KL-Grade was 15 data, so the total learning data amounts to 75 data. While the testing data used was 250 data, which consists of KL-Grade 0 to KL-Grade 4 data.

2.2. Methods
The stage of this research were image processing, feature extraction using first order, training process and testing process. Image processing implemented were image normalization using the moment method, the process of converting RGB images to grayscale, edge detection using sobel, median filters, and continued determining the histogram of the image. Gray-level histogram calculation involves single pixels. Histogram of the image founded first order information. Density probability of intensity levels occurrence calculation by dividing the values \( h(i) \) by the total number of pixels in the image [12-14].

Linear Vector Quantization used in the learning and testing stage and its algorithm used is explained by Ettaouil [15].

3. Results and discussion
The first stage of this research is image processing consisting of implemented are image normalization using the moment method, the process of converting RGB images to grayscale, edge detection using sobel, median filters, and determining the histogram of the image. The results of the image processing process are illustrated in Figure 1.
Feature extraction process is done by extracting features: entropy, kurtosis, mean, skewness, and variance, and the results as described in Table 1 to 5. Table 1 is the example of first order feature value for KL-Grade 0 or normal conditions, while Table 2 to Table 5 for KL-Grade 1 to KL-Grade 4. Minimum value of entropy, kurtosis, mean, skewness, and variance for KL-Grade 0 is $2.34 \times 10^5$, $-4.81 \times 10^7$, $2.75 \times 10^9$, $-4.81 \times 10^7$, and $2.39 \times 10^{10}$, while the maximum value is $9.98 \times 10^6$, $2.53 \times 10^7$, $2.45 \times 10^9$, $2.53 \times 10^7$, and $1.62 \times 10^{11}$.

Table 1. First order feature of data training KL-Grade 0

| No | Entropy  | Kurtosis  | Mean      | Skewness  | Variance  |
|----|----------|-----------|-----------|-----------|-----------|
| 1  | $9.98 \times 10^6$ | $-9.55 \times 10^5$ | $1.34 \times 10^9$ | $-9.55 \times 10^5$ | $1.62 \times 10^{11}$ |
| 2  | $9.92 \times 10^6$ | $1.94 \times 10^6$ | $1.15 \times 10^9$ | $1.94 \times 10^6$ | $1.61 \times 10^{11}$ |
| 3  | $9.51 \times 10^5$ | $-5.35 \times 10^6$ | $1.60 \times 10^9$ | $-5.35 \times 10^6$ | $1.52 \times 10^{11}$ |
| 4  | $9.98 \times 10^6$ | $-9.23 \times 10^5$ | $1.33 \times 10^9$ | $-9.23 \times 10^5$ | $1.62 \times 10^{11}$ |
| 5  | $9.29 \times 10^6$ | $-6.57 \times 10^6$ | $1.67 \times 10^9$ | $-6.57 \times 10^6$ | $1.47 \times 10^{11}$ |

Table 2. First order feature of data training KL-Grade 1

| No | Entropy  | Kurtosis  | Mean      | Skewness  | Variance  |
|----|----------|-----------|-----------|-----------|-----------|
| 1  | $5.40 \times 10^6$ | $-2.29 \times 10^7$ | $2.23 \times 10^9$ | $-2.29 \times 10^7$ | $7.04 \times 10^{10}$ |
| 2  | $6.47 \times 10^6$ | $-1.80 \times 10^7$ | $2.13 \times 10^9$ | $-1.80 \times 10^7$ | $8.97 \times 10^{10}$ |
| 3  | $7.48 \times 10^6$ | $-1.40 \times 10^7$ | $2.01 \times 10^9$ | $-1.40 \times 10^7$ | $1.09 \times 10^{11}$ |
| 4  | $5.40 \times 10^6$ | $-2.29 \times 10^7$ | $2.23 \times 10^9$ | $-2.29 \times 10^7$ | $7.04 \times 10^{10}$ |
| 5  | $5.90 \times 10^6$ | $-2.05 \times 10^7$ | $2.19 \times 10^9$ | $-2.05 \times 10^7$ | $7.94 \times 10^{10}$ |

Table 3. First order feature of data training KL-Grade 2

| No | Entropy  | Kurtosis  | Mean      | Skewness  | Variance  |
|----|----------|-----------|-----------|-----------|-----------|
| 1  | $6.92 \times 10^6$ | $-1.62 \times 10^7$ | $2.08 \times 10^9$ | $-1.62 \times 10^7$ | $9.83 \times 10^{10}$ |
| 2  | $6.08 \times 10^6$ | $-1.97 \times 10^7$ | $2.17 \times 10^9$ | $-1.97 \times 10^7$ | $8.26 \times 10^{10}$ |
| 3  | $6.31 \times 10^6$ | $-1.87 \times 10^7$ | $2.15 \times 10^9$ | $-1.87 \times 10^7$ | $8.68 \times 10^{10}$ |
| 4  | $6.02 \times 10^6$ | $-1.99 \times 10^7$ | $2.18 \times 10^9$ | $-1.99 \times 10^7$ | $8.15 \times 10^{10}$ |
| 5  | $6.71 \times 10^6$ | $-1.70 \times 10^7$ | $2.10 \times 10^9$ | $-1.70 \times 10^7$ | $9.43 \times 10^{10}$ |

Table 4. First order feature of data training KL-Grade 3

| No | Entropy  | Kurtosis  | Mean      | Skewness  | Variance  |
|----|----------|-----------|-----------|-----------|-----------|
| 1  | $1.00 \times 10^7$ | $1.13 \times 10^4$ | $1.27 \times 10^9$ | $1.13 \times 10^4$ | $1.63 \times 10^{11}$ |
| 2  | $1.19 \times 10^6$ | $-7.68 \times 10^7$ | $2.51 \times 10^9$ | $-7.68 \times 10^7$ | $1.03 \times 10^{10}$ |
| 3  | $3.63 \times 10^6$ | $-3.40 \times 10^7$ | $2.37 \times 10^9$ | $-3.40 \times 10^7$ | $4.19 \times 10^{10}$ |
| 4  | $2.57 \times 10^6$ | $-4.50 \times 10^7$ | $2.44 \times 10^9$ | $-4.50 \times 10^7$ | $2.69 \times 10^{10}$ |
| 5  | $3.79 \times 10^6$ | $-3.27 \times 10^7$ | $2.36 \times 10^9$ | $-3.27 \times 10^7$ | $4.43 \times 10^{10}$ |

Table 5. First order feature of data training KL-Grade 4

| No | Entropy  | Kurtosis  | Mean      | Skewness  | Variance  |
|----|----------|-----------|-----------|-----------|-----------|
| 1  | $3.68 \times 10^6$ | $-3.35 \times 10^7$ | $2.37 \times 10^9$ | $-3.35 \times 10^7$ | $4.27 \times 10^{10}$ |
| 2  | $6.54 \times 10^6$ | $-1.77 \times 10^7$ | $2.12 \times 10^9$ | $-1.77 \times 10^7$ | $9.10 \times 10^{10}$ |
| 3  | $6.28 \times 10^6$ | $-1.88 \times 10^7$ | $2.15 \times 10^9$ | $-1.88 \times 10^7$ | $8.63 \times 10^{10}$ |
| 4  | $3.36 \times 10^6$ | $-3.62 \times 10^7$ | $2.39 \times 10^9$ | $-3.62 \times 10^7$ | $3.80 \times 10^{10}$ |
| 5  | $2.64 \times 10^6$ | $-4.41 \times 10^7$ | $2.44 \times 10^9$ | $-4.41 \times 10^7$ | $2.78 \times 10^{10}$ |
The entropy relationship between KL-Grade 0 to KL-Grade 4 is figured in Figure 2. Figure 2 shows that some entropy values between KL-Grade are overlapping. This makes it very difficult to classify using linear methods; so that the appropriate method is needed to solve it. Based on figure 2 minimum value of entropy for KL-Grade 0 to KL-Grade 4 is $2.34\times10^6$, $2.00\times10^6$, $5.72\times10^5$, $1.19\times10^6$, and $2.64\times10^6$, while the maximum value is $9.98\times10^6$, $9.94\times10^6$, $9.96\times10^6$, $1.00\times10^7$, and $9.50\times10^6$.

**Figure 2.** Entropy value of KL-Grade 0 to KL-Grade 4.

Figure 3 is a graph of the value of kurtosis features for KL-Grade 0 to KL-Grade 4. The minimum value for KL-Grade 0 to KL-Grade 4 is $-4.81\times10^7$, $-5.39\times10^7$, $-2.13\times10^7$, $-7.68\times10^7$, and $-4.1\times10^7$, while the maximum value is $2.53\times10^7$, $1.8\times10^6$, $-1.44\times10^6$, $1.13\times10^4$, and $5.41\times10^6$. The average value for KL-Grade 0 to KL-Grade 4 clusters is $-1.71\times10^7$, $-2.02\times10^7$, $-1.40\times10^7$, $-2.74\times10^7$, and $-2.05\times10^7$. These values are used in the learning process using LVQ. As the case with feature entropy, it is seen that this is difficult in classification using linear method because of its overlapping value.

**Figure 3.** Kurtosis value of KL-Grade 0 to KL-Grade 4.

The minimum value of mean for KL-Grade 0 to KL-Grade 4 based on Figure 4 is $2.75\times10^8$, $1.16\times10^9$, $1.37\times10^9$, $1.27\times10^9$, and $9.42\times10^8$, while the maximum value is $2.45\times10^9$, $2.47\times10^9$, $2.49\times10^9$, $2.53\times10^9$, and $2.57\times10^9$.

![Figure 2](image2.png)

![Figure 3](image3.png)

![Figure 4](image4.png)
The average value of each cluster is $1.87 \times 10^9$, $2.01 \times 10^9$, $1.97 \times 10^9$, $2.18 \times 10^9$, and $2.07 \times 10^9$. The mean values in Figure 4 will be processed as data learning.

**Figure 4.** Mean value of KL-Grade 0 to KL-Grade 4.

The skewness values range from $-4.81 \times 10^7$ to $2.53 \times 10^7$ for KL-Grade 0, from $-5.39 \times 10^7$ to $1.80 \times 10^6$ for KL-Grade 1, from $-2.13 \times 10^7$ to $-1.44 \times 10^6$ for KL-Grade 2, from $-7.68 \times 10^7$ to $1.13 \times 10^4$ for KL-Grade 3, and $-4.41 \times 10^7$ to $5.41 \times 10^6$ for KL-Grade 4.

**Figure 5.** Skewness value of KL-Grade 0 to KL-Grade 4.

The variance values range from $2.39 \times 10^{10}$ to $1.62 \times 10^{11}$ for KL-Grade 0, from $1.97 \times 10^{10}$ to $1.61 \times 10^{11}$ for KL-Grade 1, from $7.60 \times 10^{10}$ to $1.62 \times 10^{11}$ for KL-Grade 2, from $1.03 \times 10^{10}$ to $1.63 \times 10^{11}$ for KL-Grade 3, and $2.78 \times 10^{10}$ to $1.51 \times 10^{11}$ for KL-Grade 4.
Figure 6. Variance value of KL-Grade 0 to KL-Grade 4.

After the feature extraction process is carried out the learning process using data learning. Learning using LVQ whereas learning rate parameter values is 0.5 and the number of epoch is 1000. The result of learning process is obtained weight values and this weight will be used during the testing process.

Figure 7. System accuracy determining KL-Grade 0 to KL-Grade 4.

Figure 7 illustrated the result of the testing process, this result shows that the classifying accuracy for KL-Grade 0 is 40.8 %, KL-Grade 1 40 %, KL-Grade 2 40.4 %, KL-Grade 3 76 % and KL-Grade 4 80.4 %. Accuracy for KL-Grade 0 to KL-Grade 2 does not produce very good result, this is because the conditions between these clusters have similarities. These causes osteoarthritis in the initial stages is not clearly known, so the patient is not aware of it. This is different with KL-Grade 3 and KL-Grade 4, although it does not have very high accuracy but KL-Grade 3 and KL-Grade 4 can classify well.

4. Conclusion
The research stage is image processing, image processing, using first order feature extraction, training process and testing process. The implementation of these stages obtained accuracy in determining KL-Grade 0 is 40.8%, KL-Grade 1 40%, KL-Grade 2 40.4%, KL-Grade 3 76% and KL-Grade 4 80.4%. The system's ability to determine KL-Grade 3 and KL-Grade 4 well although it does not have
very high accuracy. Meanwhile for KL-Grade 0 to KL-Grade 2, further studies are needed in order to obtain better accuracy.

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