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Pattern Recognition Using Multiclass Support Vector Machine Method with Local Binary Pattern as Feature Extraction

Nursyiva Irsalinda [1,*], Sugiyarto Surono [2] and Indah Dwi Ratna Sary [3]

[1,2,3] Department of Mathematics, Ahmad Dahlan University, Yogyakarta, Indonesia

* **Correspondence:** Email; nursyiva.irsalinda@math.uad.ac.id

Abstract: Pattern recognition is a scientific discipline usually used to classify objects into a number of categories or classes through a feature extraction method applied to recognize an object accurately. Meanwhile, Local Binary Pattern (LBP) is a texture analysis method which uses statistical and structural models for feature extraction. Moreover, a SVM method is normally used to solve non-linear problems in high dimensions to obtain an optimal solution by finding the best hyperplane through the maximization of the margin between two data classes. Therefore, this study aimed to apply pattern recognition with Local Binary Pattern (LBP) feature extraction method and Multiclass Support Vector Machine (MSVM) classification method to classify the flow of several classes of painting works including expressionism, fauvism, naturalism, realism, and romanticism. The best evaluation results using this method were obtained in the training and testing data combination of 90:10 with an accuracy rate of 83%.

Keywords: Pattern Recognition, Local Binary Pattern, Support Vector Machine, Multiclass SVM

1. Introduction

Technological developments have made data become one of the important components in every human activity. These data can be numeric, categorical, text, images, and others but the most widely used form in recent times is the images which are usually processed to produce a good identification process. Meanwhile, an important method usually used in solving problems in image processing is pattern recognition which is a scientific discipline designed to classify objects into a number of categories or classes [1]. Moreover, the numerical pattern recognition which is a statistical approach involves using multidimensional data vector as input where each component is called a feature. This is observed to be increasingly used in decision-making processes. Furthermore, a pattern recognition process through feature extraction method such as the Local Binary Pattern method is needed to recognize an object accurately.

Local Binary Pattern (LBP) is a texture analysis method which uses statistical and structural models for feature extraction [2], [3]. It works by applying a threshold to the surrounding pixels based on the pixels being observed [4], [5] and also reported to be widely used in applications involving image texture capture and classification [6], [7]. Some of its advantages includes being fixed to changes in light intensity from the same object and accuracy in recognizing an object [8]. Moreover, it can also be implemented easily and fairly quickly for feature extraction using low computational processes [2].

Classification is one of the supervised learning methods in data mining. It is usually used to find a model or function of a data set by grouping it into classes such that the data objects determined in each class label indicates they have the same characteristics or similar pattern [9]. The grouping process involves dividing the data into predetermined classes and assigning the classes according to the similarity in characteristics and the patterns in the words [10].

Support Vector Machine (SVM) is a method widely used in classifying supervised learning and was first introduced by Vapnik in 1995 [11]–[14] to solve non-linear problems in high dimensions to obtain optimal solutions [10], [15]–[18]. This method finds the best hyperplane by maximizing the margin between two classes of data [12]. Meanwhile, the margin is defined as the distance between the hyperplane and the support vector which is the closest data from the class to the hyperplane. It is important to note that SVM uses a trick kernel function to calculate data with non-linear problems in order to obtain classification results with a good level of accuracy. However, it is sensitive to noise and outliers and also reported to be less efficient to obtain complex models for large-scale data sets [9]. Meanwhile, some of its benefits include the ability to minimize errors and higher accuracy when compared with other classifications methods [19].

Pattern recognition and SVM classification methods have been widely used in previous studies. For example, Dias Aziz Pramudita and Aina Musdholifah [18] added a parameter optimization process known as the Gravitational Search Algorithm (GSA) to improve the accuracy of the SVM method in the thyroid nodule classification process. L. Jerlin Rubini and Eswaran Rerumal [20] also used the Fruit Fly Optimization Algorithm (FFOA) to select the best features in medical data which were later processed using the MKSVM method for classification. Moreover, Diya Wang and Yixi Zhao [13] predicted the feelings of investors towards stock market news using the SVM method in order to make decisions with a high level of accuracy. Jyothi S. Nayak et al. 2021 [21] also used images for gender classification while Mayur et al. [22] succeeded in showing that CNN-ECOC produced higher accuracy than ordinary CNN classification. Another research by Alita et al. *[23]* found a higher accuracy of performance for multiclass SVM method when compared with SVM method.

This present study, therefore, used the Multiclass Support Vector Machine (MSVM) method to classify pattern recognition using the Local Binary Pattern method for feature extraction. The aim was to determine the effectiveness of applying these methods in classifying the flow in a painting.

2. Materials and Methods

2.1. Pattern Recognition

Pattern recognition is a discipline usually used to classify objects into a number of categories or classes [1]. The object can be an image, a signal waveform, or any type of measurement that needs to be classified. This means pattern recognition is an important part of a system for decision-making purposes.

2.2. Local Binary Pattern Method

The Local Binary Pattern method was first introduced by Timo Ojala in 1994 [24] as a texture analysis method which uses statistical and structural models. It also has the ability to compare the gray values of the surrounding pixels [25]–[30]. The basic LBP operator was configured using 8 pixels around a center pixel and the threshold of the nth surrounding pixel was through the gray value of the center pixel and the thresholding function. The binary code generated by this LBP was, therefore, used to represent the features of the center pixel i_c.

$$LBP(x_c, y_c) = \sum_{n=0}^{n-1} s(i_n - i_c)2^n \quad (1)$$

$$s(x) = \begin{cases} 1, if & x \geq 0 \\ 0, if & x < 0 \end{cases} \quad (2)$$

where,
x_c = pixel width
y_c = pixel height
$s(x)$ = threshold function
i_n = ambient pixels from the center
i_c = center pixel

LBP is easy to implement, has lower computational level, does not require a long time for feature extraction [31], fixed to changes in light intensity from the same object, and accurate in recognizing an object [32].

2.3. Support Vector Machine Method

Support Vector Machine (SVM) is one of the methods usually used classifying supervised learning and reported to be first introduced by Vapnik in 1995 [11]–[14] to solve non-linear problems at high dimensions [27], [33] in order to obtain an optimal solution. The method finds the best hyperplane by maximizing the margin between two data classes. Meanwhile, a hyperplane is defined as a line or field separating the data between different classes while margin is the distance between the hyperplane and the support vector which acts as the closest data from the class to the hyperplane.

For example, the training data set D is

$$D_n = (x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$$

where $D = \{x_i, y_i\}_{i=1}^{n}, x_i \in R^d$ is the training data set while x_i is the input data and $y_i \in (+1, -1)$ is a class label with an output value of $+1$ (positive) or -1 (negative).

The main concept used in assigning the separator to a linear separable is the dot product between two vectors which is defined as $w^T x = \sum_i w_i x_i$. Where, w is the weighting vector and b is the bias. Moreover, the separating hyperplane was used to divide the space into two classes as indicated in the following relationship.

$$h(x) = w^T x_i + b = 0 \tag{3}$$

Meanwhile, the separator function for the two classes is as follows

$$w^T x_i + b \geq +1 \;\; for \;\; y_i = +1 w^T x_i + b \leq -1 \;\; for \;\; y_i = -1$$

Where, $\frac{|b|}{\|w\|}$ is the perpendicular distance of the dividing plane from the center of the coordinates and $\|w\|$ is the Euclidean distance (Euclidean norm) from w.

Moreover, the Quadratic Programming (QP) problem was the step used in determining the minimum point by considering the equation constraints.

$$\min_{w,b} \frac{1}{2} \|w\|^2 \tag{4}$$

with constraint function

$$y_i(wx_i + b) - 1 \geq 0, i = 1,2, \dots, m$$

It is also possible to resolve the optimization problem through the use of the Lagrange multiplier as indicated in the following equation:

$$L = \frac{1}{2} \|w\|^2 - \sum_{i=1}^{n} \alpha_i (y_i((wx_i + b) - 1)) \tag{5}$$

Where, α_i is the Lagrange Multiplier which is zero or positive $(\alpha_i \geq 1)$. The problem was, therefore, optimized by minimizing L to w and b and maximizing α_i. The equation was later modified as follows with due consideration for the nature of the optimal point $L = 0$:

Condition 1

$$\frac{\partial Lp}{\partial w} = 0 \rightarrow w = \sum_{i=1}^{n} \alpha_i y_i x_i \tag{6}$$

Condition 2

$$\frac{\partial Lp}{\partial b} = 0 \rightarrow w = \sum_{i=1}^{n} \alpha_i y_i = 0 \tag{7}$$

The substitution of *w* changed the equation into a Lagrange duality

Max

$$L_D = \sum_{i=1}^{n} \alpha_i - \frac{1}{2}\sum_{i,j} \alpha_i \alpha_j y_i y_j x_i \cdot x_j \quad (8)$$

Condition 1

$$\sum_{i=1}^{n} \alpha_i y_i = 0$$

Condition 2

$$\alpha_i \geq 0, i = 1,2, \dots, n$$

2.4. Kernel

The Support Vector Machine learning process to determine the support vectors depends on the dot product of the data in the feature space i.e. $\Phi_i(x_i) \cdot \Phi(x_j)$. It is, therefore, possible to replace this dot product calculations with trick kernel functions $K(x_i, x_j)$ which implicitly define the transformation and formulated as follows:

$$K(x_i, x_j) = \Phi_i(x_i) \cdot \Phi(x_j) \quad (9)$$

One of the trick kernel functions commonly used in the general classification of Support Vector Machines is Radial Basis Function (RBF) which is presented as follows.

$$K(x_i, x_j) = \exp\left(-\frac{\|x_i - x_j\|^2}{2\sigma^2}\right) \quad (10)$$

Previous studies have already shown that the Radial Basis Function (RBF) kernel has a better accuracy rate than other kernels [34]. Therefore, it was applied in this research for classification using the Multiclass Support Vector Machine method.

2.5. Multiclass SVM

The Support Vector Machine (SVM) method was first introduced by Vapink only to classify data into two classes. Subsequent research has, however, been conducted to increase its ability to classify data for more than two classes. Moreover, there are two approaches to solve SVM problems for multiclass and the first includes the combination of all data in an optimization problem while the second involves building a multiclass classifier or several binary SVMs. The first approach requires solving a more complex and computationally high optimization problem and this limits its development. Meanwhile, the second such as "one-against-all" approach is usually used to implement multiclass SVM.

This one-against-all (OAA) method is usually used to determine the *k* binary SVM models where k is the number of classes [35], [36]. It also tests p l with all data from the class with label +1 and those from other classes with label -1. An example of a classification problem with five classes and five binary SVMs is presented in the following table:

Table 1. OAA Method.

$y_i = 1$	$y_i = -1$	Hypothesis
Class 1	Not class 1	$f_1(x) = (w_1)x + b_1$
Class 2	Not class 2	$f_2(x) = (w_2)x + b_2$
Class 3	Not class 3	$f_3(x) = (w_3)x + b_3$
Class 4	Not class 4	$f_4(x) = (w_4)x + b_4$
Class 5	Not class 5	$f_5(x) = (w_5)x + b_5$

3. Results

This research used secondary data which includes painting data retrieved from several internet websites. A total of 420 images on flow of painting were obtained and these include 70 for expressionism, 100 for fauvism, 80 for naturalism, 70 for realism, and 100 for romanticism. These image data were later divided into training and testing samples at different combinations including 90:10, 75:25, 50:50, and 25:75.

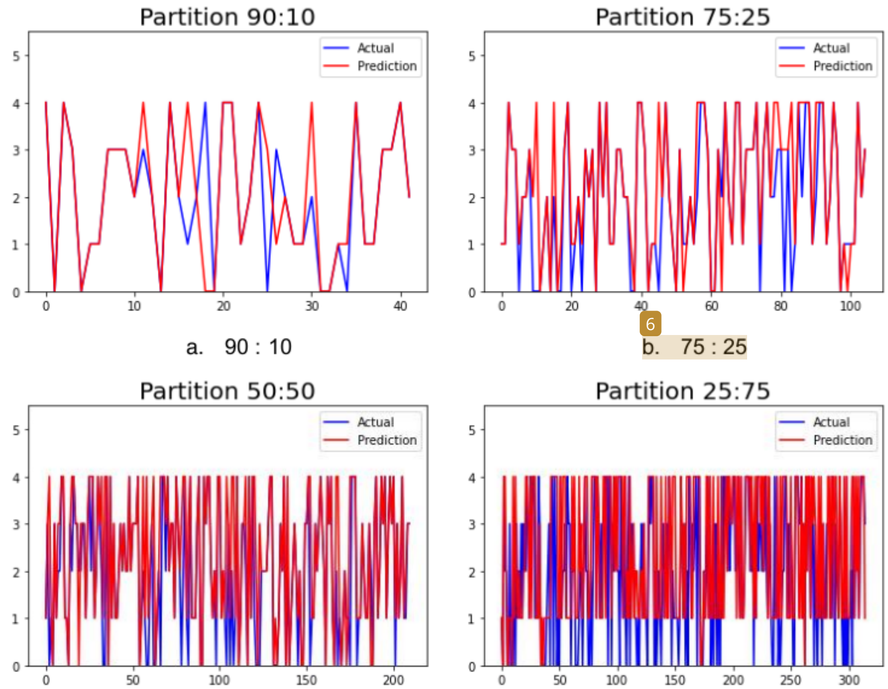
3.1 Result of feature extraction method LBP

Each of the images was resized and converted to a grayscale in the LBP to determine the pixel values at each point. These values were made into threshold and their binary values encoded to produce LBP values for all pixel points in the image. The final result of the feature extraction is presented on a histogram and one image was discovered to have 256 values based on the frequency of occurrence from 0 to 255. These outputs are also indicated in the following table:

Table 2. LBP Value.

Data	Value							
	0	1	2	3	4	5	...	255
Image 1	833	117	99	79	126	49	...	937
Image 2	676	86	272	85	86	12	...	807
Image 3	754	110	96	76	95	42	...	920
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮
Image 420	393	67	226	110	57	14	...	603

The data from the LBP extraction process were used as the input for the classification conducted through the Multiclass Support Vector Machine (MSVM) using the Radial Basis Function (RBF) kernel. The results of the prediction against the actual data for each of the proportions are, therefore, shown in the following graphic images:

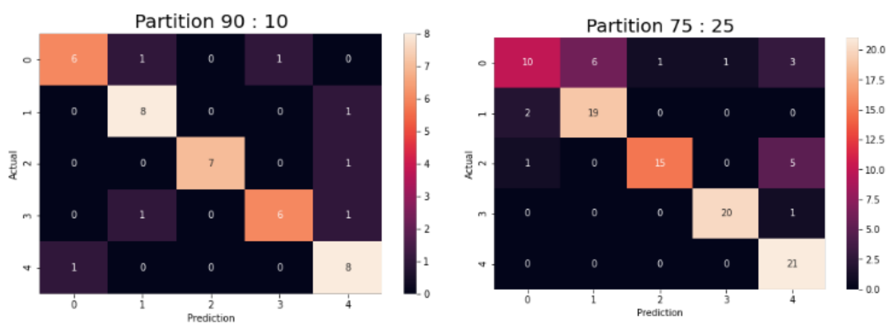


a. 90 : 10   b. 75 : 25

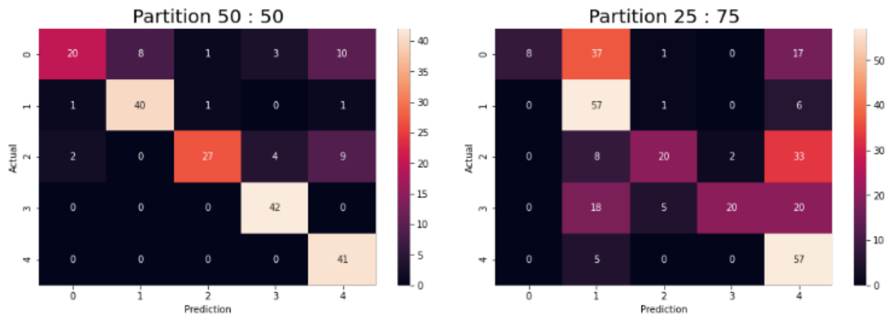
c. 50 : 50   d. 25 : 75

Figure 1. Prediction results and the actual data.

Figure 1 shows the 90:10 combination produced predictions which are almost the same as the actual data. Moreover, the classification results for each training and testing data combination were evaluated using a confusion matrix to determine the deviations in the prediction process and the findings are presented as follows.



a. Partition 90:10   b. Partition 75:25



c. Partition 50:50 d. Partition 25:75

Figure 2. Confusion Matrix on each Data Partition.

Figure 2 shows the correct prediction results are located in the diagonal part of the table. Moreover, the performance of the MSVM classification model was determined based on precision, recall, and accuracy as indicated in Figure 3:

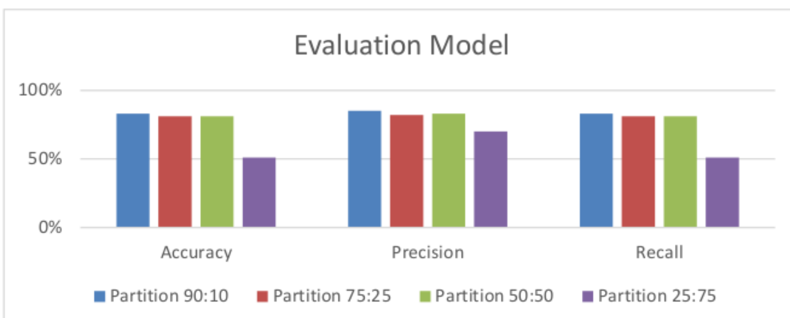


Figure 2. Evaluation of Each Data Partition.

Figure 3 shows that 90:10 proportion had an accuracy rate of 83%, 75:25 had 81%, 50:50 had 81%, and 25:75 had 51%. This, therefore, means the best evaluation of pattern recognition classification using LBP and MSVM feature extraction were obtained through training and testing data combined at 90:10.

4. Conclusions

Data analysis and discussion showed that pattern recognition through Local Binary Pattern feature extraction and Multiclass Support Vector Machine were used to classify works of art into five classes which include expressionism, fauvism, naturalism, realism, and romanticism. It was discovered that the classification made by combining training and testing data at 90:10 had an accuracy rate of 83%, 75:25 had 81%, 50:50 had 81%, and 25:75 had 51%. This, therefore, means the best evaluation of pattern recognition classification using LBP and MSVM feature extraction were obtained through training and testing data combined at 90:10.

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Conflict of interest

The authors declare no conflict of interest.

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