
RECOGNITION OF CALLIGRAPHY WRITING PATTERNS USING THE ZERNIKE MOMENT METHOD AND SUPPORT VECTOR MACHINE

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Abstract: *One of the great arts of Islam that is very attached to Muslims is the art of calligraphy. The art of writing in calligraphy is of many types because the art of calligraphy is generally handwritten by someone called khatat and each khatat has its own technique for writing calligraphy. There fore there are many variations of calligraphy writing, even with the same type of writing. With so many variations of the type of calligraphy writing, technological innovation is needed to recognize variations of each type of calligraphy. Types of calligraphy diwani, diwaji jali, naskhi and tsuluts are the objects of this study. The Zernike Moment method is a feature extraction method that has the advantage of being invariant to rotate (resistant to rotation) and can help identify calligraphy types well based on their features. And the Support Vector Machine method is a good method for identifying calligraphy types by finding the best hyperplane. The combination of the Zernike Moment method and the Support Vector Machine is proven to produce good accuracy in recognizing calligraphy types based on their features, the accuracy obtained in identifying calligraphy types is 95%.*

Keywords: *Pattern Recognition, Zernike Moment, Support Vector Machine, Calligraphy*

Abstrak: Salah satu seni besar Islam yang sangat melekat di kalangan umat Islam adalah seni kaligrafi. Seni menulis kaligrafi banyak macamnya karena seni kaligrafi umumnya ditulis tangan oleh seseorang yang disebut khatat dan setiap khatat mempunyai teknik penulisan kaligrafi tersendiri. Oleh karena itu terdapat banyak variasi penulisan kaligrafi, bahkan dengan jenis tulisan yang sama. Dengan banyaknya variasi jenis tulisan kaligrafi, diperlukan inovasi teknologi untuk mengenali variasi setiap jenis kaligrafi. Jenis kaligrafi diwani, diwaji jali, naskhi dan tsuluts menjadi objek penelitian ini. Metode Zernike Moment merupakan salah satu metode ekstraksi ciri yang mempunyai kelebihan yaitu bersifat invarian terhadap rotasi (tahan terhadap rotasi) dan dapat membantu mengidentifikasi jenis-jenis kaligrafi dengan baik berdasarkan ciri-cirinya. Dan metode Support Vector Machine merupakan metode yang baik untuk mengidentifikasi jenis kaligrafi dengan mencari hyperplane terbaik. Kombinasi metode Zernike Moment dan Support Vector Machine terbukti menghasilkan akurasi yang baik dalam mengenali jenis kaligrafi berdasarkan ciri-cirinya, akurasi yang didapat dalam mengidentifikasi jenis kaligrafi adalah 95%.

Kata kunci: Pengenalan Pola, Momen Zernike, Mesin Vektor Pendukung, Kaligrafi

INTRODUCTION

The art of calligraphy is one of the great Islamic arts that is very attached to Muslims (AR, 2022). Where the art of calligraphy is often found in mosques or buildings that have an Islamic nuance, where the art of calligraphy is combined with the holy verses of the Koran, hadiths,

or the words of wisdom of the ulama. The art of calligraphy itself has various types of writing. The types of calligraphy writing that are often competed in MTQ (musabaqah tilawatil qur'an) events are Naskhi, Tsulutsi, Farisi, Diwani, Diwani Jali, Kufi, and Riq'ah calligraphy types. The art of calligraphy is generally handwritten by someone called khatat.

Each khatat has its own technique for writing calligraphy (Musri, 2022). Therefore, it is not surprising that the types of calligraphy writing have many variations, even though they are the same type. Therefore, to be able to recognize the type of calligraphy writing which has so many variations, technological innovation is needed to be able to recognize the type of calligraphy writing correctly, accurately and efficiently (Rafiq, 2020).

In this research the author intends to create research that can recognize types of calligraphic writing which has so many types and variations of calligraphic writing. So the researchers used the Zernike Moment and Support Vector Machine methods to analyze whether these two methods were able to recognize patterns of calligraphic writing types correctly and produce good accuracy. Where the Zernike Moment method is a feature extraction method based on shape which aims to extract calligraphic images based on their shape. Then the Support Vector Machine method is used as a recognition method to recognize types of calligraphic writing based on images that have been previously extracted using the Zernike Moment method.

The Zernike Moment method is a shape-based feature extraction method where the feature extraction method aims to detect or search for significant areas in the image and depends on the intrinsic characteristics and application (Aziza, 2021). This feature is used in the pattern to obtain the final classifier of the class. Zernike Moment has orthogonality properties, and has properties that do not depend on image rotation. Zernike Moment has the advantage that it will not change the image being played. Another advantage of Zernike Moment is the ease of image reconstruction due to the orthogonality function.

The Support Vector Machine method is a pattern recognition method where the pattern recognition method aims to identify or recognize objects in the image (Safitri et al., 2019). The

pattern recognition method is used to recognize patterns of letters, numbers, sounds, signatures, the quality of objects that have changed slightly. can be identified and named through its characteristics (Kartikasari, 2020). The Support Vector Machine method is a method that works on the principle of finding the best hyperplane that separates two classes in the input space and finding the maximum point (Dharmawan, 2022). Support Vector Machine has the advantage of good accuracy. Another advantage of the Support Vector Machine method is the fast learning process. In this research the author focuses on method analysis. Where the focus on the method analysis in question is to analyze whether the combination of the Zernike Moment and Support Vector Machine methods can produce a good level of accuracy and efficiency in recognizing types of calligraphic writing which has so many types and variations of writing.

METHOD

Research Methods

The method used in this research is a quantitative research method. Quantitative research methods are a method used to answer research problems related to data in the form of numbers and statistical programs (Balaka, 2022). Quantitative research methods use data, namely numbers, with added emphasis on objective measurement of results accompanied by statistical analysis. The numbers used in statistical analysis come from an objective scale of measurement of units of analysis called variables (Suci Sukmawati et al., 2023). These numbers will then be analyzed using appropriate statistical application software to reveal significant relationships or differences between variables (Rizki Rahmadanoor, Normajatun, 2020). System Development Methods. The data collection techniques used in this research are as follows:

1. The interview technique is a data collection technique carried out by seeking information and knowledge sourced from experts working in fields related to this research (Casro et al., 2020). So that the author gets relevant data references about calligraphy.
2. Observation is a data collection technique by directly observing an object to search for information and knowledge related to research, especially in research on pattern recognition for calligraphic writing using the Zernike Moment and Support Vector Machine methods (Sulaiman, 2020).
3. Data collection was carried out by taking 25 samples of calligraphy writing images from each type of calligraphy studied in this research with an image size of 320 x 240 pixels.

RESULTS AND DISCUSSION

Data Used

The dataset used to recognize patterns of calligraphic writing types comes from calligraphy image data extracted from Zernike Moment features. The dataset used has 6 features resulting from Zernike Moment feature extraction, here the author takes 3 features to carry out manual calculations using the Support Vector Machine method which looks like table 1 below:

Table 1. Data Used

No	Types of Calligraphy	Value Extraction Results of Zernike Moment Features		
		X1	X2	X3
1	Diwani 1	62.8	187.0	2.1
2	Diwani Jali 1	54.1	188.2	2.5
3	Naskhi 1	86.5	192.0	1.9
4	Tsuluts 1	78.0	189.4	2.8

Data Normalization

The initial dataset has data that has not been normalized, visible in feature

values that have lots of numbers after the comma. Therefore, data normalization will be carried out. Data normalization consists of various ways. In this research, the author uses rounding feature values so that there are no commas in the feature values. The normalization results dataset can be seen in table 4.3 below:

Table 2. Normalization Results Dataset

No	Types of Calligraphy	Value Extraction Results of Zernike Moment Features		
		X1	X2	X3
1	Diwani 1	67	187	2
2	Diwani Jali 1	54	188	3
3	Naskhi 1	87	192	2
4	Tsuluts 1	78	189	3

Determination of Output Value (y)

From the normalization results, the output value (y) will be determined by giving the value y = 1 for the first class for which the decision function will be searched and giving the value y = -1 for the other classes. So it will produce 4 decision functions according to the existing classes. The results of determining the output value (y) can be seen in table 3 below:

Table 3. X and Y Values

No	X1	X2	X3	Y
1	67	187	2	1
2	54	188	3	-1
3	87	192	2	-1
4	78	189	3	-1

Determination of Weight (w) and Bias (b) Values

To calculate the weight (w) value, the formula $y_i(w \cdot x_i + b) \geq 1$ is used for the first class whose decision function will be searched and the formula $y_i(w \cdot x_i + b) \leq -1$ is used for the other classes. Where $i = 1, 2, 3, \dots, N$. Then several equations are obtained, namely:

$$(w1 + w2 + w3 + b) \geq 1 \text{ Untuk } y1 = 1, x1 = 67, x2 = 187, x3 = 2 \dots\dots\dots(1)$$

$$(w1 - w2 - w3 - b) \leq -1 \text{ Untuk } y2 = -1, x1 = 54, x2 = 188, x3 = 3 \dots\dots\dots(2)$$

$$(w1 - w2 - w3 - b) \leq -1 \text{ Untuk } y3 = -1, x1 = 87, x2 = 192, x3 = 2 \dots\dots\dots(3)$$

$$(w_1 - w_2 - w_3 - b) \leq -1 \text{ Untuk } y_4 = -1, x_1 = 78, x_2 = 189, x_3 = 3 \dots\dots\dots(4)$$

After getting the equation above, we search for the values of w_1 , w_2 and w_3 and the value of b by eliminating equations 1 and 2, equations 1 and 3, equations 1 and 4 as follows:

Eliminate equations 1 and 2:

$$\begin{array}{r} 67w_1 + 187w_2 + 2w_3 + b = 1 \dots\dots\dots (1) \\ 54w_1 - 188w_2 - 3w_3 - b = -1 \dots\dots\dots (2) \\ \hline 13w_1 + 375w_2 + 5w_3 + 2b = 2 \dots\dots\dots (5) \end{array}$$

The results of eliminating equations 1 and 2 produce equation 5. Eliminate equations 1 and 3:

$$\begin{array}{r} 67w_1 + 187w_2 + 2w_3 + b = 1 \dots\dots\dots (1) \\ 87w_1 - 192w_2 - 2w_3 - b = -1 \dots\dots\dots (3) \\ \hline -20w_1 + 379w_2 + 4w_3 + 2b = 2 \dots\dots\dots (6) \end{array}$$

The results of eliminating equations 2 and 3 produce equation 6. Eliminate equations 1 and 4:

$$\begin{array}{r} 67w_1 + 187w_2 + 2w_3 + b = 1 \dots\dots\dots (1) \\ 78w_1 - 189w_2 - 3w_3 - b = -1 \dots\dots\dots (4) \\ \hline -11w_1 + 376w_2 + 5w_3 + 2b = 2 \dots\dots\dots (7) \end{array}$$

The results of eliminating equations 3 and 4 produce equation 7. Eliminate w_3 using equations 5 and 6 by cross multiplying the w_3 index

$$\begin{array}{r} 13w_1 + 375w_2 + 5w_3 + 2b = 2 \dots\dots\dots (5) \\ -20w_1 + 379w_2 + 4w_3 + 2b = 2 \dots\dots\dots (6) \\ \hline 52w_1 + 1500w_2 + 20w_3 + 8b = 8 \\ -100w_1 + 1895w_2 + 20w_3 + 10b = 10 \\ \hline 152w_1 - 395w_2 - 2b = -2 \dots\dots\dots (8) \end{array}$$

The result of eliminating w_3 becomes equation 8. Eliminate w_3 using equations 6 and 7 by cross multiplying the w_3 index

$$\begin{array}{r} -20w_1 + 379w_2 + 4w_3 + 2b = 2 \dots\dots\dots (6) \\ -11w_1 + 376w_2 + 5w_3 + 2b = 2 \dots\dots\dots (7) \\ \hline -100w_1 + 1895w_2 + 20w_3 + 10b = 10 \\ -44w_1 + 1504w_2 + 20w_3 + 8b = 8 \\ \hline -56w_1 + 391w_2 + 2b = 2 \dots\dots\dots (9) \end{array}$$

The result of eliminating w_3 becomes equation 9. Eliminate w_2 using equations 8 and 9 by cross multiplying the w_2 index

$$\begin{array}{r} 152w_1 - 395w_2 - 2b = -2 \dots\dots\dots (8) \\ -56w_1 + 391w_2 + 2b = 2 \dots\dots\dots (9) \\ \hline 59431w_1 - 154445w_2 - 782b = -782 \\ 22120w_1 - 154445w_2 - 790b = -790 \\ \hline 37311w_1 + 8b = 8 \end{array}$$

Find the value of w_1
 $37311w_1 = 8$
 $w_1 = 0,0002$

Find the value of w_2 using equation 9 substituting for w_1

$$\begin{array}{r} -56w_1 + 391w_2 + 2b = 2 \dots\dots\dots (9) \\ -56(0,0002) + 391w_2 + 2b = 2 \\ -0,0112 + 391w_2 + 2b = 2 \\ -0,0112 + 391w_2 = 2 \\ w_2 = 0,005 \end{array}$$

Find the value of w_3 using equation 7 substituting w_1 and w_2

$$\begin{array}{r} w_1 = 0,0002; w_2 = 0,005 \\ -11w_1 + 376w_2 + 5w_3 + 2b = 2 \dots\dots\dots (7) \\ -11(0,0002) + 376(0,005) + 5w_3 + 2b = 2 \\ -0,0022 + 1,88 + 5w_3 + 2b = 2 \\ 1,8778 + 5w_3 = 2 \\ w_3 = 0,02 \end{array}$$

Find the bias value using equation 6 substituting w_1 , w_2 , w_3

$$\begin{array}{r} w_1 = 0,0002; w_2 = 0,005; w_3 = 0,02 \\ -20w_1 + 379w_2 + 4w_3 + 2b = 2 \dots\dots\dots (6) \\ -20(0,0002) + 379(0,005) + 4(0,02) + 2b = 2 \end{array}$$

$$-0,004 + 1,895 + 0,08 + 2b = 2$$

$$1,971 + 2b = 2$$

$$b = 0,01$$

Determination of Hyperplane Values

To determine the hyperplane value, the following equation is used:

$$f(x) = w1.x1 + w2.x2 + w3.x3 + b = 0$$

From the equation above, combined with the weight(w) and bias(b) values, the hyperplane values are obtained as follows:

$$f(x) = 0.0002.x1 + -0.005.x2 + 0.02.x3 + 0.01 = 0$$

After getting the first hyperplane value, the above calculation process is carried out again starting from determining the output value (y) to determining the hyperplane value until getting 4 hyperplanes, which in the SVM one against all hyperplane method is a decision function that will determine the class of the data being trained and tested.

Hyperplane as a Decision Function

From the results of calculations carried out repeatedly, 4 hyperplanes are obtained as decision functions as follows:

$$f1(x) = 0,0002.x1 + -0,005.x2 + 0,02.x3 + 0,01 = 0$$

$$f2(x) = -0,001.x1 + 0,004.x2 + 0,07.x3 + 0,04 = 0$$

$$f3(x) = 0,0002.x1 + -0,004.x2 + 0,7.x3 + 0,006 = 0$$

$$f4(x) = 0,01.x1 + 0,004.x2 + 0,1.x3 + -0,1 = 0$$

Data Testing

In table 4 below is the test data where 1 sample of test data was taken to carry out the pattern recognition process for types of calligraphy writing which will be carried out using 4 decision functions.

Table 4. Test Data

No	Types of Calligraphy	Value Extraction Results of Zernike Moment Features		
		X1	X2	X3
1	Naskhi 20	34.6	165.7	3.0

Table 5. Normalization Results Test Data

No	Types of Calligraphy	Value Extraction Results of Zernike Moment Features		
		X1	X2	X3
1	Naskhi 20	35	166	3

Table 6. X and Y Values

No	X1	X2	X3	Y
1	35	166	3	1

Table 7. One Against All Method Decision Function

$y_i = 1$	$y_i = -1$	Hypothesis
Diwani	Bukan Diwani	$f1(x) = (w1.x1 + w2.x2 + w3.x3 + b)$
Diwani Jali	Bukan Diwani Jali	$f2(x) = (w1.x1 + w2.x2 + w3.x3 + b)$
Naskhi	Bukan Naskhi	$f3(x) = (w1.x1 + w2.x2 + w3.x3 + b)$
Tsuluts	Bukan Tsuluts	$f4(x) = (w1.x1 + w2.x2 + w3.x3 + b)$

By using the test data shown in table 7, pattern recognition of calligraphic writing types was carried out using the one against all method decision function equation with class = sign(f(x)). The sign function used is to check the results of calculations carried out on test data. Test results on test data that produce the decision function with the maximum value will be given the value $y_i = 1$, while other decision functions will be given the value $y_i = -1$. The test results can be seen in table 4.10 below:

Table 8. Test Results

No	Test Data			One Against All Method Decision Function	y_i
	X1	X2	X3	$f1(x) = \text{sign}(w1.x1 + w2.x2 +$	

				$w3.x3 + b$	
1	35	166	3	$\text{sign}(-0,753)$	-1
2	35	166	3	$\text{sign}(0,879)$	-1
3	35	166	3	$\text{sign}(1,449)$	1
4	35	166	3	$\text{sign}(1,414)$	-1

Table 8 shows the results of data introduction using 4 decision function equations. From the results of data introduction, a value of 1 is obtained for decision function 3 and a value of -1 for decision functions 1, 2, and 4. Where decision function 3 is the naskhi calligraphy type class and decision functions 1, 2, and 4 are the diwani calligraphy type class, diwani jali, and tsuluts. Therefore, the results of the data testing carried out were correct in that the data tested was Naskhi type calligraphy.

Table 9. Introduction Results

No	Test Data			Data Introduction Results	Information
	X1	X2	X3		
1	35	166	3	-1	Bukan Kelas Diwani
2	35	166	3	-1	Bukan Kelas Diwani Jali
3	35	166	3	1	Kelas Naskhi
4	35	166	3	-1	Bukan Kelas Tsuluts

The results of introducing other test data are no longer done manually as above, but are introduced using an application that has been created.

Implementation

Application Initial Display

The initial form is the main page for running the program to be worked on.



Figure 1. Initial Display Form

Image Input Display

The display on this form involves inputting the image by pressing the Open I button, then the system will direct you to select the data to be tested, then the system will automatically display the input image.

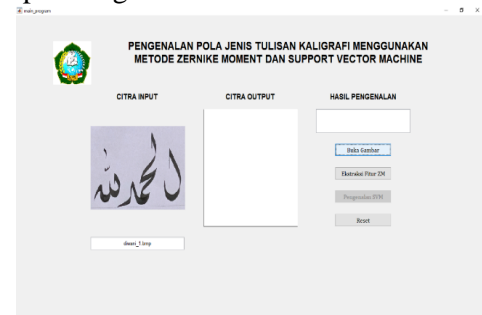


Figure 2. Image Input Display Form

Zernike Moment Extraction View

The display on this form will extract features from the image by pressing the ZM Feature Extraction button, then the system will display the image extracted from Zernike Moment on axes2.

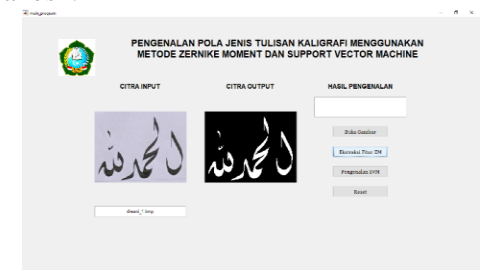


Figure 3. Zernike Moment Extraction Display Form

Display of Classification Results

The display in this form is a display of the recognition results on the input image. To display the recognition results

by pressing the SVM Recognition button, the system will immediately display the recognition results of the image inputted in edittext2.

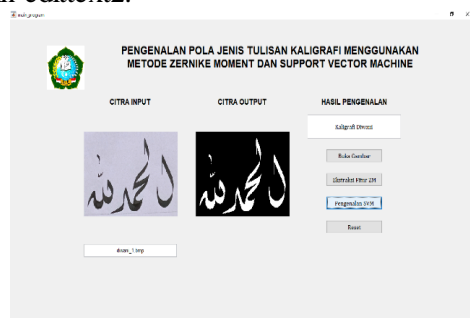


Figure 4. Display form for the results of recognizing calligraphy image patterns

Reset Button Display

The display on this form is used to display the system back to normal, that is, by pressing the reset button, the system will immediately reset the display back to normal.

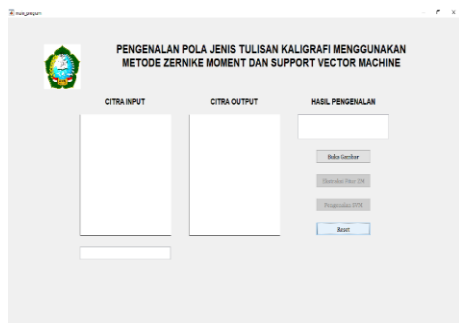


Figure 5. Reset Button Display Form

CONCLUSION

Based on the objectives of this research, it can be concluded that: The Support Vector Machine method is a binary classification method that divides 2 classes with a value of 1 for the first class and -1 for the second class. The problem found in this research was the introduction of 4 types of calligraphy. Therefore, to overcome this problem, the Support Vector Machine Multiclass method was used. Where the Multiclass Support Vector Machine works the same as a regular Support Vector Machine which classifies binary. However, the difference is that there will be as many models as the number of classes. Where

this research uses 4 classes, it will produce 4 models. The way it works is that the first class is given a value of 1 while the other classes will be given a value of -1 to get the first model, the second class is given a value of 1 and the other classes are given a value of -1 to get the second model, and so on in the same way according to the number of classes used so that there are as many models as the number of classes used.

The combination of the Zernike Moment method and Support Vector Machine which was implemented using the Matlab application was proven to be successful in obtaining good accuracy results of 95%.

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