



An Approaching Machine Learning Model: Tile Inspection Case Study

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ARTICLE INFO

Article history:

Received 09 January 2020

Accepted 20 January 2020

Published 31 January 2020

ABSTRACT

Clothing, food, and shelter are three basic types of needs in our lives. If one of the basic needs is not met then there can be an imbalance in our lives. One of the basic needs is to build a house. House needs a tile or roof to cover of a building that can protect all weather influences. One company in Majalengka only uses fleeting vision in inspection process. This can result in a decrease in work productivity. This paper proposed an approach machine learning model for classification of defects was carried out in the inspection process. Feature extraction was performed using the Local Binary Pattern (LBP) method to obtain training features. The next stage is training (training) to the characteristics of training that has been obtained. Furthermore, the database obtained from the training results will be used to classify tile image test data using the Support Vector Machine (SVM) method. From the test results, the system is made capable of classifying defects of a maximum accuracy value of 63.21%. The results obtained are the best accuracy value generated is 76.67% with LBP parameters used are 256×256 cell size and radius 2. While for SVM parameters use Polynomial kernel type or RBF with OAA multiclass.

Keywords:

*Tile-Inspection, Vision,
Feature Extraction, SVM,
LBP*

1. Introduction

Various problems often arise in the ceramic tile production chain. Every failure is immediately reflected on the final ceramic tile. The final production phase is sorting ceramic tiles. The purpose of this phase is to reject damaged parts such as physical defects and color shade. In most cases, the final phase of tile sorting in quality classes is based on the ability of human perception [1].

One of the things needed in building a house is tile. Tile or roof is a cover of a building on top of a building that can protect all weather influences. There are several types of tile used, including clay tile, ceramic tile, concrete tile [2].

One type of tile used is clay tile. With so many producers in making tile, there is a competition between companies that always give the best for consumers. One that can be used as a reference in the competition is quality. Quality is a reference that can be used as a benchmark for the progress of industry. If a company can keep up its quality well, the company has good competitiveness and the ability to meet the needs of consumers [3].

PT. XYZ is a tile manufacturer located in Majalengka. In the competition that occurs in meeting customer needs is maintaining the quality of products made by PT. XYZ. This company can make 10000 pieces in one production which usually takes two days. In its manufacture there is an average of defects found in making tile that is 1000 pieces. And usually the defect that is known after the product has reached the hands of customers that cause some complaints given by the customer. There is a possibility that causes problems that occur at PT. XYZ.

The problem that they were cause is visual inspection. It is commonly used in both manufacturing tasks and nonproduction environments. In manufacturing tasks, the purpose is to verify that a product is free of defects before installation in the next level of assembly or final distribution to the customer. In non-production environments, the objective is to determine whether the features indicative of a “target” are present and prevent potential negative impacts. Many fields in which visual inspection is used are considered high consequence due to the potentially high costs of inspection errors-injury, fatality, loss of expensive equipment, scrapped items, rework, or failure to procure repeat business. Such high-consequence fields include nuclear weapons, nuclear power, airport baggage screening, aircraft maintenance, food industry, and medicine.

Table.1 Several Factors Impact for Inspection Proses

Task	Individual
<ul style="list-style-type: none"> ● Defect Rate ● Defect Type ● Defect Saliency ● Defect Location ● Complexity ● Standards ● Pacing ● Multiple Inspection ● Overlays ● Automation 	<ul style="list-style-type: none"> ● Gender ● Age ● Visual Acuity ● Intelligence ● Aptitude ● Personality ● Time in Job ● Experience ● Visual Lobe ● Scanning Strategy
Environmental	Organizational
<ul style="list-style-type: none"> ● Lighting ● Noise ● Temperature ● Shift Duration ● Time of Day ● Vigilance ● Workplace Design 	<ul style="list-style-type: none"> ● Management Support ● Training ● Retraining ● Instruction ● Feed forward Information ● Feedback ● Job Rotation
Social	
<ul style="list-style-type: none"> ● Pressure ● Consultation 	<ul style="list-style-type: none"> ● Isolation ● Communication

The challenge of visual inspection in the 21st century. Some researchers argue that human visual inspection continues to have an important role in the 21st century. In the case example, the nature of this inspection remains unchanged compared to the traditional inspection process of the 20th century. In other cases, the nature of this inspection has evolved, in large part due to recent advances in the use of automated techniques for visual inspection. As a result, practitioners in the 21st century face many challenges. On the one hand, they must successfully identify and apply lessons learned from the past that continue to influence the process of visual inspection in the 21st century. On the other hand, they must pursue a new research path to find solutions to the problems of modern times, such as those introduced by automation.

In the inspection process at one company in Majalengka for our study case, the producer only uses a short sight in this inspection where the limitation of human vision results in the inspection process requiring more time to perform

one defect scanning process. If the eyes are focused on objects that are close within a relatively long period time can cause eye fatigue due to eye muscles must work harder [4]. Eye muscle fatigue and eye nerve fatigue cannot cause permanent eye disease but increase workload, accelerate fatigue, rest frequently, lose working hours and reduce job satisfaction, decrease the quality of production, increase the frequency of errors, disrupt concentration and reduce work productivity[5]. Image processing is currently being developed which can help optimize the inspection process. An image can be described by an object and complex and can represent it only by visualizing data [6].

Several studies have been conducted in the classification of defects such as research by Y. Ji [7]. This research is entitled Apple Grading Method Based on Features of Color and Defect. Classifying apple defects based on color features. The method used in this study is Support Vector Machine (SVM). The result can classify defects by 98%. Research conducted by H. Q. Bong [8] with the research title Vision-based Inspection System for Leather Surface Defect Detection and Classification. This study uses the Support Vector Machine (SVM) method to identify defects in the skin. The result can classify defects by 98%. Based on previous research and problems that occur, the writer will make a system design from the classification of defects. The author uses the Support Vector Machine (SVM) method in the classification of defects. Because SVM has advantages in terms of data optimization [9].

2. Literature Review

2.1 Tile

Tile is a part of the structure of building materials which is on the top of the building and serves as a cover for a building [10]. Roof tiles are usually made from a mixture of clay and other mixed materials such as padas and sand, which combine with water will form a homogeneous mixture, then do the grinding so that it can pulverize the particles so that it is easily printed according to the desired shape and then dried and burned until cooked and hard [11]. In addition, to add strength to the tile also used a mixture such as natural fibers, asbestos fibers, glass fibers, asphalt adhesives and metal ores that strengthen the quality of the tile. By remembering the function of the roof tile as an important role in a building to protect the house from the sun, rain and other weather changes. Then the tile must have good mechanical properties, such as compressive strength, striking strength, hardness and other properties.

Clay is a type of clay that is plastic containing high levels of silica and alumina. Clay is a secondary mineral and is classified as hydrated aluminum silicate. The minerals (clay) are very commonly used in the ceramic industry. Clay minerals are constituents of sedimentary rocks and are the main constituents of soil. Clay is a material that has a particle size $< 2 \mu\text{m}$ in diameter and can be found near the surface of the earth. General characteristics of clay include chemical composition, crystal layer structure and size. All clay minerals have an attraction for water. Some are easy to enlarge and can have a volume twice as wet. Most clays form when rocks come into contact with water, air or gas. Examples are rocks that come into contact with water heated by magma (molten rock), sedimentary rocks in the sea or on the lake floor[12].

The physical characteristics of clays are sticky and are easily formed when moist, but hard and cohesive when dry. Most clay has the ability to absorb ions from a solution and release these ions when conditions change. Water molecules are very attracted to the surface of clay minerals, so when a little clay is added to the water slurry will form because the clay distributes itself into the water. Mixing large amounts of clay and a little water will produce sludge that can be formed and dried to produce a hard and solid material. Clay is a mineral that has many uses and applications, not only as ceramic materials, building materials, paper coating materials, or pharmaceutical materials, but the use of clay has undergone development. Today clay is also widely used as an adsorbent, catalyst support, ion exchange, depending on the physical properties of the clay[13].

2.2 Digital Image Processing

A digital image $a[m,n]$ described in a 2D discrete space is derived from an analog image $a(x,y)$ in a 2D continuous space through a sampling process that is frequently referred to as digitization. The 2D continuous image $a(x,y)$ is divided into N rows and M columns. The intersection of a row and a column is termed a pixel. The value assigned to the integer coordinates $[m,n]$ with $\{m=0,1,2,\dots,M-1\}$ and $\{n=0,1,2,\dots,N-1\}$ is $a[m,n]$. In fact, in most cases $a(x,y)$ – which we might consider to be the physical signal that impinges on the face of a 2D sensor – is actually a function of many variables including depth (z), color (λ), and time (t).

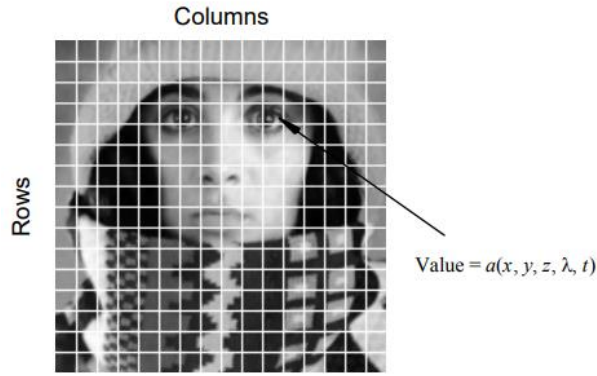


Figure 1. Digitation Process

The image shown in Figure 1 has been divided into $N = 16$ rows and $M = 16$ columns. The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value. The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply quantization.

Image processing aims to improve the image quality so that it is easily understood by humans or machines [12]. There are two types in image processing namely analog image and digital image. Continuous images obtained from optical systems from the results of receiving analog signals can be called analog images. The image generated through the digitization of analog images is digital images [13]. An example of a digital image is a two-dimensional picture and can be easily processed. Each photo in the form of a digital image (for example coming from a digital camera) can be processed through certain software. For example, if the camera shots look rather dark, the image can be processed to be brighter. There is a possibility of separating photos of people from their backgrounds. The picture shows a simple thing that can be done through digital image processing [6].

An image can also be defined as a function $f(x, y)$ of size M rows and N columns, with x and y being spatial coordinates, and the amplitude off at the coordinate point (x, y) is the intensity value or gray level of the image at that point [14].

Digital images can be seen in the form of a matrix in equation 2.1:

$$f(x,y)= \begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & \vdots & \vdots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix} \quad (2.1)$$

In a variety of image-forming systems an appropriate model for the transformation of the physical signal $a(x,y)$ into an electronic signal $c(x,y)$ is the convolution of the input signal with the impulse response of the sensor system. This system might consist of both an optical as well as an electrical sub-system. If each of these systems can be treated as a linear, shift-invariant (LSI) system then the convolution model is appropriate. The definitions of these two, possible, system properties are given below:

$$\begin{aligned} \text{Linearity -} & \quad \text{If } a_1 \rightarrow c_1 \quad \text{and} \quad a_2 \rightarrow c_2 \\ & \quad \text{Then } w_1 \cdot a_1 + w_2 \cdot a_2 \rightarrow w_1 \cdot c_1 + w_2 \cdot c_2 \\ \\ \text{Shift-Invariance -} & \quad \text{If } a(x, y) \rightarrow c(x, y) \\ & \quad \text{Then } a(x - x_o, y - y_o) \rightarrow c(x - x_o, y - y_o) \end{aligned}$$

2.3 Local Binary Pattern

Local Binary Pattern is defined as the comparison of the binary pixel value at the center of the image with 8 pixel values around it [15]. Local Binary Pattern is a descriptor for clarifying images based on image texture. So, a picture

that is 3x3, where the binary value at the center of the image is compared to the surrounding value. [16] If the intensity of the middle pixel is greater than the central binary then the value set is 1, If it is smaller than 0. With 8 pixels around it means that there are $2^8 = 256$ possible combinations of Local Binary Pattern codes.

The Local Binary Pattern (LBP) method has been used in various applications. LBP algorithm was applied to recognize human faces [17] and facial expressions [18]. LBP histogram was extracted from Gabor map of human faces. This histogram is then combined into one vector. The vector is considered a pattern vector [19]. In another implementation, a combination of LBP texture features and Self-Organizing Map is applied to identify the quality of the paper.

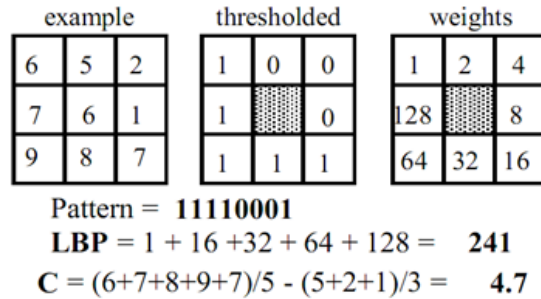


Figure 2. Weighting Example of LBP

LBP is an operator for texture descriptions based on the signs of difference between neighboring pixels and central pixels [4, 5]. Figure 1 shows an example of calculating LBP values. For each pixel value in the image, the binary code is obtained by setting the environment with the middle pixel value. This binary code can be considered a binary pattern. The neighbor pixel becomes 1 if the pixel value is greater than or equal to the threshold value, and becomes 0 if the pixel value is smaller than the threshold. The equation basic of LBP can be given as follows:

$$LBP(x_c y_c) = \sum_{n=0}^7 2^n g(I_n - I(x_c y_c)) \quad (2.2)$$

$LBP(x_c y_c)$ is a LBP value at the center pixel $(x_c y_c)$. I_n and $I(x_c y_c)$ are the values of neighbor pixel and center pixel respectively. Index n is the index of neighbor pixels. The function $g(x)$ will be zero if $x < 0$ and $g(x) = 1$ if $x \geq 0$. One method that is quite widely used to get the texture and sharpness features of an image is Local Binary Pattern (LBP) and is also commonly known as a feature approach technique. The workings of this method by comparing the pixel values processed with neighboring pixel values or can be called the thresholding technique [15]. The formulae for finding the value of the LBP method can be stated as follows with $g(x)$ is a function of thresholding [9]:

$$g(x) = \{ 0, x < 0 \quad 1, x \geq 0 \quad (2.3)$$

In texture analysis applications it is desirable to have features that are invariant or powerful for the rotation of input images. As LBP, P, R patterns are obtained by circularly sampling around a central pixel, operators on LBP have labels marked with P and R. P represents the number of neighboring pixels used in computing while R is the radius between the center point pixel and the neighbor pixel. Note that each LBP code bit has the same level of significance and that two sequential bit values may have completely different meanings. Actually, LBP Code can be interpreted as an index kernel structure. By definition, LBP operators are not affected by monotonous gray-scale transformations which maintain a sequence of pixel intensities in the local environment.

2.2 Support Vector Machine (SVM)

The Support Vector Machine (SVM) algorithm is a method that was first introduced by Vapnik in 1992. SVM is often used because it has the ability to find that has optimal global properties [6]. And SVM itself only stores a small amount of training data to be used at the time of prediction [16].

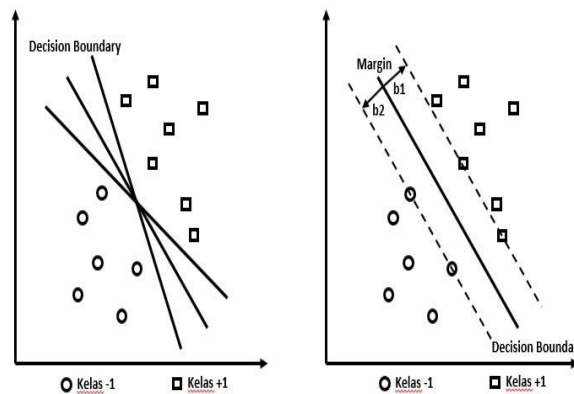


Figure 3. Margin hyperplane SVM

The best hyperplane searches that functions as a separator of two data classes in the input space including the concept of classification with SVM In Figure II.8 shows some data that is a member of two data classes namely +1 and -1. Class -1 is represented by data symbol in the form of a circle, while class +1 is represented by data symbol in the form of a square cage. The best hyperplane separator between the two classes can be found by measuring the hyperplane's margin and finding its maximum point. The distance between the hyperplane and the closest data from each class is the margin. The closest data is called a support vector. Figure 2.8 shows the best hyperplane because it is located in the middle of both classes. Support vector here is the circle and square data that is crossed by a dashed line (margin line) [16]. Model SVM [17]:

$$\text{Data point : } x_i = \{x_1, x_2, \dots, x_n\} \in \mathbb{R}^n \quad (2.4)$$

$$\text{Data class : } y_i \in \{1, -1\} \quad (2.5)$$

$$\text{Data pairs and classes: } \{(x_i, y_i)\} \quad (2.6)$$

It is assumed that classes 1 and -1 can be completely separated by a dimensionless hyperplane, which is defined,

$$\vec{w} \cdot \vec{x} + b = 0 \quad (2.7)$$

$$\text{Data points } x_i \text{ including class -1 can be formulated } \vec{w} \cdot \vec{x} + b \leq -1 \quad (2.8)$$

Data points x_i belonging to class +1 can be formulated

$$\vec{w} \cdot \vec{x} + b \geq +1 \quad (2.9)$$

The largest margin can be found by maximizing the value of the distance between hyperplane.

Information:

- N : lot of data,
- n : data dimensions or number of features,
- y_i : data class, $K(x, x_i)$ is a kernel function,
- x_i : data point,
- w : data weights,
- b : bias.

There is also a way to implement multi-class SVM by combining several binary SVMs or by combining all data consisting of several classes into a form of optimization problems [18].

1. One-Against-All is a method that is built into a binary SVM model (where k is the number of classes). Every i in SVM is trained with all data contained in i with positive or negative labels.
2. One-Against-All is method constructed a binary classification model where k is the number of classes. Each classification model is trained on data from two classes. There are several methods for testing after the classification model is completed. One method is to use the voting method.

2.3 System Design

Overall the workflow of the system designed is: First, tile image retrieval then proceeds to the preprocessing stage which includes resizing, RGB to a grayscale image, then proceed with the feature extraction process using LBP, and finally analyzing the characteristics and classified using SVM. There are pictures of the stages of the system design process as shown in Figure 4 below:

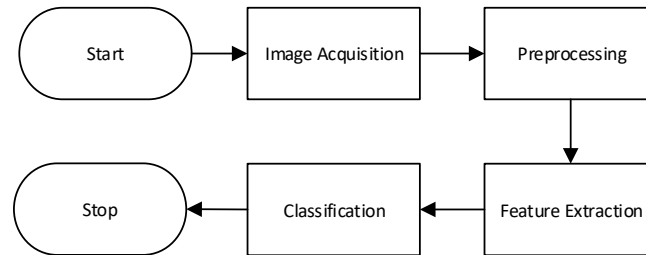




Figure 4 System Design

2.4 Image Acquisition

The acquisition is the initial stage to get tile images for training data and test data. Digital images are obtained by the process of recording images using a camera and the format * jpg. Training data and test data are obtained at the company being studied. To validate the proposed solution, the database obtained is based on taking samples in the field and then drawing from some of the samples is processed into an inspection box. The data collection process we did 10 times in two classifications (normal, crack) is shown in table 2.

Table 2. Rooftile sampling condition

No	Roof-tile	The Condition
1		Normal
2		Crack

2.5 Preprocessing

The prototype that we used in this research was to make an automatic conveyor and to have a camera holder on the top that was used to inspect the ceramic tile. In the lower position, there is a fixation structure for the lighting system. For this purpose, LED strings with 120 LEDs and 2 meters long are used. It is placed at the bottom of the structure to avoid shadows and / or reflections. The material used is Medium Density Fiber (MDF). The prototype has dimensions of 60 cm × 60 cm × 80 cm.

Inside the inspection box (figure 5) the interior is deliberately colored matte black, aiming to make higher contrast with lightweight roof tiles, the most common pattern on the market. The roof tile being analyzed has a maximum dimension of 48 cm × 48 cm. The camera module used is Raspberry Pi, 5 Megapixel Sunny P5v04a “. Positioned at a distance of 79.7 cm tiles based on calculations $1/s' = 1/f - 1/s$ resulting in a Soil Fetching Distance (GSD) of 0.3212 cm. This sensor is not the best for this type of application. However, this is a good choice, because one of the proposals for this work is to keep the system cheap. However, with better camera quality, this system is expected to achieve higher accuracy.

The initial process is carried out pre-processing after the input image is obtained. The input image will be processed in order to get improved quality from the image itself. One of them by using resize which is done to equalize the size of the input image varies. After that multiply the RGB image with a certain coefficient so that it can convert the image from RGB to grayscale. After converting to a gray image, the next step is to calculate the binary value. We can calculate the binary value by dividing the image into smaller parts or often called masks / kernels / templates. Here I use a template with a size of 256 x 256, 512x512 and 1024x1024. Next, calculate the intensity value of each pixel in the 256 x 256, 512x512 and 1024x1024 template. Here we have 65.536 pixels, which the pixel center will be used as a reference for comparison with the other 8 pixels.

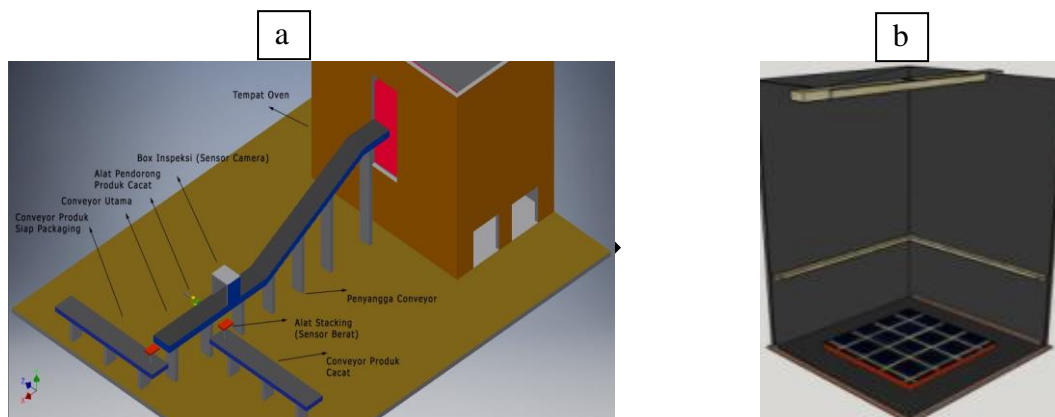


Figure 5 A Whole Process from production chain (a), inside the inspection box (b)


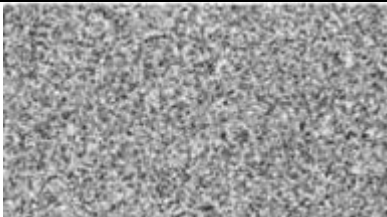

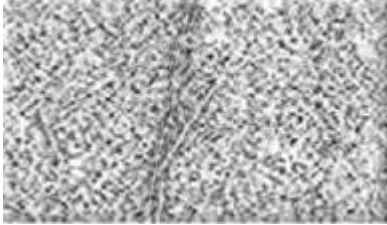
Next is to give a comparison value. The black square represents the center of the pixel which will then be compared to the gray box. If the pixel value in the gray box is smaller than the center of the pixel then the comparison value is 0, conversely if the value is greater or equal to the center of the pixel then the comparison value is 1. Now, arrange the binary values with conditions clockwise or counterclockwise. So now we get the binary value = 11110001

2.6 Feature Extraction

LBP can process using natural textures as objects, input from a file from jpg or bitmap will produce an output in the form of a histogram, so this output will be extracted on each LBP bitmap. In this case the pattern of the histogram will be considered as a sample pattern. We divided the data into two groups. The first group will be used as a reference pattern and the second group for testing patterns. Reference patterns can be made with an average number of sample patterns. After the reference pattern is created, we store it in the pattern database. Pattern classifiers will find minimum differences between input patterns as test patterns and reference patterns in the database. The pattern of inputs can be decided to belong to a particular group if a minimum difference has been reached in that group. We increase the contrast of psoriasis images by using even distribution of the histogram.

Feature extraction is done to take the characteristics of an image that represents the characteristics of an object. Then the characteristics obtained will be used as a differentiator between one character with another character. In the LBP feature extraction, a thresholding process is performed which determines the middle value in the grayscale image of the pre-processing results presented in the form of a matrix with the condition that if the surrounding pixel is greater than the pixel value at the midpoint then it will be given a value of “1”. If the pixel has a value less than the midpoint value (the pixel being processed) then it is given a value of “0”[9].

Table 2. Feature Extraction in LBP Process

No	Roof Tile Image	LBP Process
1		
2		

2.6 Classification

The classification process follows up on the results of the feature extraction process. Data from feature extraction are classified using Support Vector Machine Multiclass. The training data is then taken from a database that has been extracted features based on the type of tile as test data so that it is processed immediately. After the process completed the next evaluate can be proceed to the test process.

2.7 Accuracy Calculation

Accuracy is a measurement for checking the system between the predicted value and the real value so that it can produce a truth value. If the accuracy value is large, the system is good for detecting tile defect classifications. Mathematically can be written as follows:

$$N = \frac{x}{y} \times 100\%$$

Information:

N = accuracy

x = amount of data is correct

y = total data

3. Analysis

System testing is based on several parameters obtained during the system programming process. Each test has results that are represented in tables and graphs. In this test using tile image data with training data comparison values with test data of 1: 2. Furthermore, there are 3 classifications of classification which are good tile, white stone defect tile, cracked defect tile. There are several similar tests to find out how well the system's ability to classify defects

3.1 Accuracy Test Results on Image Resize Sizes

Testing is done by changing the cell size parameters of (256 x 256), (512 x 512), and (1024 x 1024) with radius 1. The type of kernel used is RBF and will also compare the results of multiclass SVM one against one (OAO) and also one against all (OAA) The accuracy results obtained can be seen in the table 3.1.

Table 3.1 Accuracy Test on Image Resizes

No.	Resize	OA0 (%)	OAA (%)
1	(256 x256)	66.67	70
2	(512 x 512)	60	66.7
3	(1024 x 1024)	56.67	63.33

In the results obtained, the accuracy with the highest value is resized (256 x 256) with the type one against all having a value of 70%. It can be concluded that the smaller the cell size used the higher the level of accuracy.

3.2 Accuracy Test Results Against Local Binary Pattern Radius Parameters

Testing is done by changing the Local Binary Pattern parameter, which is the radius parameter that will be done 3 times of testing. The type of kernel used is RBF with image resize (256 x 256) and will also compare the results of multiclass SVM one against one (OA0) and also one against all (OAA) The accuracy results obtained can be seen in the table 3.2.

Table 3.1 Accuracy Test Against Local Binary Pattern Radius Parameters

No.	Radius	OA0(%)	OAA(%)
1	1	66.67	70
2	2	70	76.67
3	3	66.67	76.67

In the results obtained, the accuracy with the highest value is resized (256 x 256) with the type one against all having a value of 70%. It can be concluded that the smaller the cell size used the higher the level of accuracy.

3.3 Accuracy Testing Results for SVM Kernel Types

Tests carried out with cell size parameters (256 x 256) with a radius of 2. The type of kernel used is RBF, polynomial, and linear. And also, will compare the results of multiclass SVM one against one (OA0) and also one against all (OAA) The accuracy results obtained can be seen in the table 3.3.

Table 3.1 Accuracy Test for SVM Kernel Types

No.	Kernel	OA0(%)	OAA(%)
1	RBF	70	76.67
2	Polynomial	70	76.67
3	Linear	73.33	70

In the results obtained, the accuracy with the highest value is in the polynomial kernel and RBF kernel with one against all has a value of 76.67%. It can be concluded that the type of polynomial kernel or RBF is more suitable in this study because it is better than other kernels and also the appropriate multiclass in this study is one against one.

4. Online License Transfer

Based on the results of system testing to classify tiles that have been done using LBP feature extraction method and SVM classification method, the best accuracy value obtained is 76.67% with LBP parameters used are cell size 256 x 256 and radius 2. As for the parameters SVM uses Polynomial or RBF kernel types with OAA multiclass.

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