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Zero-One Matrix on *Tudung Saji* Pattern via Image Processing

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ABSTRACT

Pattern recognition is a method for classifying or describing the quantitative measurement of features of any object, data, or source. It involves any input that depends on the context of the study, such as biometric data, sensor data, signals, images, and so on. Prior research had been conducted on *tudung saji*, with a particular emphasis placed on ethnographic research that was related to group theory. In order to advance the study of the relationships between *tudung saji* and group theory, additional analysis is undertaken to examine the pattern of *tudung saji* within certain finite matrix rings. This analysis involves studying the zero-one matrix that is obtained through image processing. It is important to understand the process of pattern recognition to produce the output as a classification result from the feature extraction of the input. The study focuses on the stages of image preprocessing, which include scaling, grayscale conversion, and thresholding. The binarization image is classified through feature extraction using the image of tudung saji patterns. The binarization image produces a binary value. The threshold value is calculated by using the Otsu's Method. This method evaluates the binary value by comparing the threshold value with the grayscale value. The result assists researchers in the subsequent classification of tudung saji patterns into group theory by means of analysing the finite zero-one matrix. Hence, the classification of *tudung saji* patterns can be achieved by utilising finite zero-one matrices, which allows for a more comprehensive analysis of these patterns from the standpoint of group theory. In light of these considerations, a mathematical analysis is conducted on the patterns of *tudung saji* under the field of pattern recognition. In this analysis, the image of the *tudung saji* pattern serves as the input for data processing, resulting in the production of a finite zero-one matrix.

1. Introduction

Weaving is the discipline or art of interlacing yarn in order to create cloth or fabric. In Malaysia, weaving is not limited solely to the production of fabric. *Tudung saji* is one of the traditional weaving arts in Malaysia. The tudung saji is a food cover that is predominantly used by Malays to cover their meals. *Tudung saji* can be made in various sizes, and these *tudung saji* are also used as home decorations by many people nowadays [1]. Generally, there exists a connection between

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mathematics and culture, as well as *tudung saji*. In previous studies conducted by Adam [1] and Zamri [2], the patterns of *tudung saji* were examined from a mathematical perspective. The discussions primarily revolved around the triaxial template patterns and their connection to group theory and graph theory. Studies on *tudung saji* have also focused on ethnographic studies related to the Mutual Interrogation Method and its relations with group theory. The study on the relations of *tudung saji* with mathematics, especially group theory, has been limited until now, with no progress made by the researchers to advance the study. There have been no previous reports in the literature on the method of pattern recognition for analysing the patterns of *tudung saji* through image processing and the zero-one matrix. Therefore, this further analysis proceeds to study the pattern of *tudung saji* using finite matrix rings. This is done through the analysis of the zero-one matrix that results from the process of pattern recognition, specifically image processing.

The patterns of *tudung saji* are so diverse that nearly every region in Malaysia is involved in their making, including Melaka, Terengganu, and Kelantan. *Tudung saji* has many patterns and variations. Almost every *tudung saji* pattern from different regions has similar patterns, such as Pati Sekawan (Flock of Pigeons), Bunga Tanjung (Cape Flower), Butang (Buttons), Kapal Layar (Sailboats), Jari Ketam (Crab Finger), and so on [3]. This paper focuses on the study of the *tudung saji* pattern from the perspective of mathematical theory. It emphasises image processing for pattern recognition in order to classify the tudung saji pattern using a matrix form. The investigation and exploration of the information contained behind an image, in order to identify a pattern, is driven by artificial intelligence. The zero-one matrix, which is produced by image processing, is utilised in subsequent group theory analysis to learn how to categorise the *tudung saji* patterns into groups. This is done by using the image of triaxial template patterns of *tudung saji.*

In the present day, pattern recognition has emerged as a highly significant field of knowledge due to its crucial role in various interconnected domains of information technology (IT). These domains encompass big data analytics, biometric identification, security, and artificial intelligence (AI). Pattern recognition has been utilised in diverse studies across various fields, each harbouring its unique set of interests. The automatic (machine) recognition, description, classification, and grouping of patterns are important problems in various engineering and scientific disciplines, including biology, psychology, medicine, marketing, computer vision, artificial intelligence, and remote sensing [4]. Andrian *et al*., [5] provided usage examples of pattern recognition, including face recognition, fingerprint recognition, signature recognition, vehicle number recognition, retina recognition, and batik motive recognition. The technique involves categorising the properties or characteristics of an object in such a way that it allows for the distinction or comparison of said object with others within its own category. In order to further enhance the sparsity of the basis matrix, the researchers adopted a threshold-sparse constraint. This constraint transforms the basis matrix into a zero-one matrix, which in turn can enhance the accuracy of facial feature recognition [6]. The identical approach is employed in the conversion of the *tudung saji* picture into a zero-one matrix.

A method of pattern recognition is utilised in order to classify patterns of *tudung saji* as a finite zero-one matrix. This allows for the categorisation of the patterns as a zero-one matrix. The basis matrix of a zero-one matrix is formed from the result of image processing. The entries of the matrices are determined by the binarization image, which generates binary values. The aim of this paper is to focus on the transformation of *tudung saji* patterns into a finite matrix, which is a zero-one matrix. The discussion focused specifically on the methods used, namely image processing through pattern recognition methods. These methods demonstrate that an image of a *tudung saji* pattern can be represented as a zero-one matrix. The matrix is then analysed as a symmetric matrix using the classification method, in which certain definitions and properties of a symmetric matrix are applied.

The classification of patterns for tudung saji is discussed as a continuation of this analysis, with a focus on group theory and graph theory.

2. Pattern Recognition Process

2.1 Pattern Recognition

Pattern recognition is a process in which the input is analysed using a specific algorithm to identify or classify any input by utilising specific properties in the feature extraction process. According to Davies [7], pattern recognition is a task that humans are able to achieve "at a glance" with little apparent effort. Pattern recognition, to a large extent, is a process that involves analysing shape in order to achieve its goal. In contrast, statistical pattern recognition treats sets of extracted features as abstract entities that can be used to classify objects on a statistical basis. This is often done by comparing their mathematical similarity to sets of features for objects with known classes. Classifying or describing the quantitative measurement of features or the main nature of an object is a scientific endeavour.

The analysis of *tudung saji* patterns is conducted by examining various properties of matrices using the pattern recognition method in order to achieve the research objective. According to Bhamare and Suryawanshi [8], the objective of pattern recognition is to identify historical items and relationships, specifically, to extract patterns from the input data. The procedures primarily pertain to image analysis, although it is not the main type of application. According to Andrian *et al.,* [5], the purpose of pattern recognition is to define a group or category of patterns based on the characteristics possessed by the pattern. In other words, it is the recognition of the pattern that distinguishes one object from another object. Pattern recognition applications are prevalent in many fields. These fields include image processing, speech and biometric recognition, aerial photo interpretation, medical imaging, and diagnosis. Therefore, this study focuses on image processing in pattern recognition. It pertains to the process of identifying patterns of *tudung saji*. This process involves analysing and interpreting the underlying structure or features of *tudung saji*. The result is a finite matrix, specifically a zero-one matrix, which is then applied for further analysis from the perspective of group theory.

Pattern recognition is extensively used in various fields of mathematics, including pure and applied mathematics, statistics, and computer science. According to a previous study conducted by Bhattacharyya *et al.,* [4], pattern recognition using neural networks is considered the best possible way to utilise available sensors, processors, and domain knowledge in order to make decisions automatically. Pattern recognition is also applied with fuzzy sets in order to determine the relationship between two picture fuzzy sets [9]. It is employed in useful applications, which include image processing, machine learning, and data analysis. Therefore, pattern recognition in mathematics can be related to a variety of ideas, including topology, sequences and series, symmetry, fractals, and so on. In order to complete this study, the highlighted ideas are based on the concept of symmetry in pattern recognition. In the process of weaving *tudung saji*, the concept of symmetry plays a vital role in balancing the pattern. According to Zamri *et al.,* [3], the triaxial template of the *tudung saji* pattern possesses geometrical and symmetrical properties. Therefore, it can be inferred that the output of an image processing procedure that involves pattern recognition also satisfies the symmetrical properties. The zero-one matrix resulting from image processing consists of the binary values 0 and 1. The classification of the product through feature extraction is based on the properties of a symmetrical matrix. Since the triaxial template of *tudung saji* satisfies symmetrical properties, the zero-one matrix produced from the perspective of a symmetrical matrix also satisfies symmetrical properties.

The algorithm or set of rules implemented for the classification phase depends on the characteristics that have been studied. Singh [10] has identified six types of pattern recognition algorithms, which include statistical techniques, structural techniques, the neural network approach, the fuzzy model, the hybrid model, and template matching. Different algorithms have different uses and purposes. For example, the hybrid algorithm is employed to create hybrid models, wherein multiple classifiers are utilised to identify patterns. On the other hand, statistical algorithms are employed within organisations to develop statistical models. The template matching algorithm is used to determine the similarity and match the pattern by using the image as an object that is being processed. Therefore, the classification of images for *tudung saji* patterns can be achieved through three fundamental stages: preprocessing, feature extraction, and classification. In this study, the pattern recognition algorithms are not designed to provide automatic identification of patterns; rather, they apply certain mathematical theorems to classify the patterns. In the image processing of *tudung saji*, different processes apply different existence algorithms. The Bicubic interpolation method is used for scaling, the weighted average method is used for grayscale, and Otsu's method is used for thresholding.

In order to initiate the classification process of the *tudung saji* pattern into a zero-one matrix, the initial step involves identifying images of patterns. This is done by going through the process of image processing, specifically pre-processing. The subsequent steps of the procedure are then followed as depicted in Figure 1.

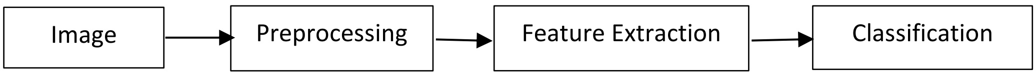

Fig. 1. Process of pattern recognition

The information obtained from the image as an input is processed through image preprocessing, and the output is then used to classify or test the characteristics of an object through feature extraction. The classification of an object is determined by the tested features.

2.2 Image Processing

The image classification or recognition system consists of four primary steps: data loading (importing), image preprocessing, feature extraction, and classification of the input (image). The system imports the data from the sources that link to it for data loading. At this stage, images of tudung saji with different patterns are tested and the image of tudung saji is defined in formed of binary value. The image is assumed to be a two-dimensional function, $f(x,y)$ where (x,y) is defined as the grayscale value. According to Bangare *et al.,* [11], an image can be described as a two-dimensional function $f(x,y)$ in which x and y represent spatial (plane) coordinates. The amplitude of f at any pair of coordinates (x,y) is referred to as the intensity or grey level of the image at that point. At this stage, it is imperative to ensure that the image possesses optimal quality to obtain the most favourable outcomes in the image processing. One of the elements that need particular attention is the contrast of the image. According to Mustafa *et al.,* [12], Contrast enhancement is a pre-processing technique used to improve the quality of images for certain uses, such as machine learning or human vision. Image enhancement through contrast alteration impacts the number of image pixels at each grey level of the image.

Image preprocessing occurs after the loading of data, at which point the chosen image is utilised. This step aims to convert the normal image to a binary image by scaling, grayscale, thresholding and binarization processes. In reference to Omarov and Cho [13], the preprocessing of the image involves the application of several procedures. These procedures include thresholding, smoothing, filtering, resizing, and normalisation. The aim of the procedure is to simplify and enhance the accuracy of the subsequent algorithm for final classification. The process of image processing can be succinctly represented as depicted in Figure 2.

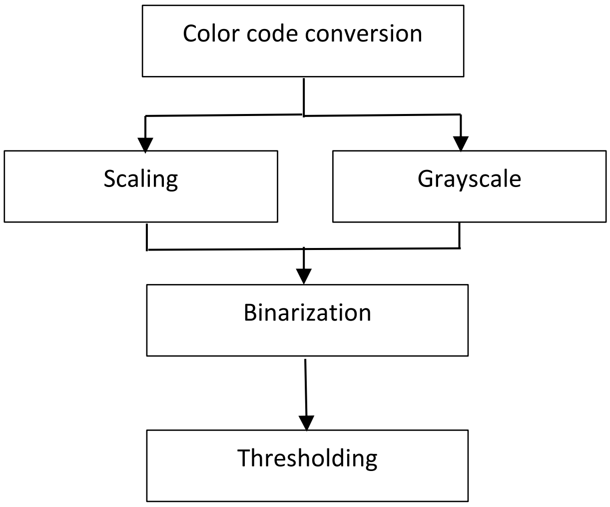

Fig. 2. Image Preprocessing step

There are two processes that must be completed for the colour conversion code: scaling and grayscale. The act of resizing an image and modifying its dimensions is referred to as scaling. Scaling is employed for the purpose of modifying the visual appearance of an image, adjusting the amount of information contained within a scene representation, or serving as a low-level preprocessor in a multi-stage image processing chain that operates on features of a specific scale. Scaling compresses or enlarges an image in the coordinate directions. Images in a digital computer are represented as arrays of numbers of finite size. By means of scaling, an image is partitioned into a grid of pixels, forming rectangles. After this process is completed, each individual pixel is assigned a pixel value. Generally, a pixel is related to the dimension of an image. The dimensions of an image provide the values for both width and height, with the image's size being measured in pixels. The scaling process is important because it determines the measurement of the primary colours, red, green, and blue (RGB), which represent the intensity of the primary colours from each pixel at this stage. The intensity value (RGB) of tudung saji for each pattern is obtained by completing the resizing of the image using the method of Bicubic interpolation. This involves adjusting the original size into a few smaller sizes (shrinking), which was a sample of the study.

Bicubic interpolation is a classic algorithm in the real-time image processing systems, which can achieve good quality of image at a relatively low hardware cost and is also the fundamental component of many other much more complex algorithms [14]. It is utilised in image processing for pattern recognition and image resampling. Several sizes are being tested to determine the accuracy of the extraction features for classifying zero-one matrices and groups. The accuracy of the results is determined by the quality of the interpolation. Achieving the study's target requirements begins with the best interpolation performance, as image processing is a continuous step in recognising an image pattern. Boukhtache *et al.*, [15] state that Bicubic interpolation is widely utilised in real-time image processing systems due to its high-quality interpolation. The real-time implementation of Bicubic interpolation necessitates a substantial amount of hardware resources, particularly in terms of the number of multipliers, as it entails a high level of computational complexity. The bicubic algorithm possesses the advantages of having more accurate image magnification and a faster processing speed

[16]. Because of the advantages of this method and its utilisation in MATLAB software, this study employed Bicubic interpolation to resize the image of tudung saji patterns in order to obtain the RGB value.

The scaling process allows for the increase and decrease in image sizes, affecting the dimensions (in pixels). During the process of scaling, variations in image sizes result in distinct data representations. The larger the image size, the greater the data value that is processed, and vice versa. The process involves resizing the images in the train data and test data to images of pixels. This is done to ensure that the image does not contain excessive information that needs to be processed during the classification process [17]. The value of the primary colour (RGB) of an image in different sizes is found by repeating the same process. According to [17], the process involves changing the pixel size, followed by finding the RGB value for each pixel. The RGB value of the *batik burung* phoenix represents 5×5 pixels exclusively. The original image size 5184×3456 pixels is scaled to 50×50 pixels, and RGB value for the same motive is represented for 5×5 pixels only [5]. It is clear where each size provides distinct data information. Each image with a true colour, RGB value is used to determine the grayscale value in the grayscale step. Later, the binary image produces a binary value based on a threshold value in the thresholding step. The dimensions of the image change according to the process of scaling, resulting in a diversified size for the image in this study. The dimension test must be square, which implies that the width value must be equal to the height value. The purpose is to ensure that the dimensions of the image adhere to the principles of symmetry.

The next step is the grayscale process, which eradicates all colour information from each pixel, leaving only its luminance. The grayscale value replaces the RGB value of each image pixel [5]. In order to define the value of RGB, the image is converted to a binary image by checking the range of combination colours for black and white. The RGB value determines the binary value that is produced later in the thresholding stage.

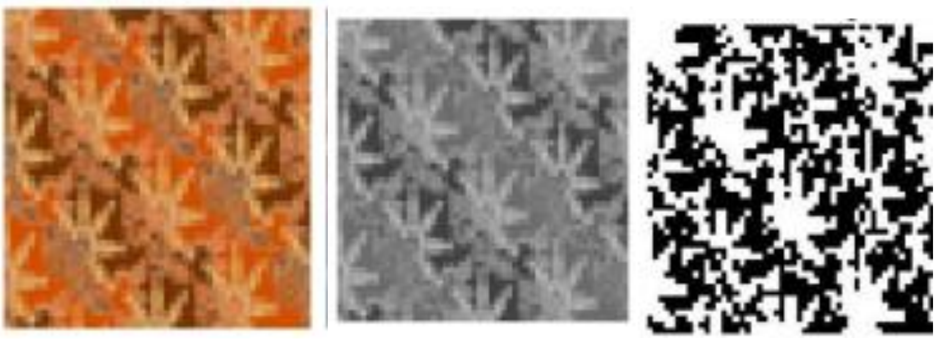

Fig. 3. Image transformation from normal image, grayscale image and binary image [18]

After scaling, the images from Figure 3 undergo a grayscale process that transforms them into images with a greyish appearance. At this stage, the RGB values of the image are converted to grayscale values. Generally, there are four algorithms that can be applied to convert a colour image to grayscale [18,19].

i. lightness method average: $\left(\max(R,G,B)+\min(R,G,B)\right)/2$
ii. average method: $(R+G+B)/3$
iii. luminosity method: $0.21R+0.72G+0.07B$
iv. weighted average method: $0.2989R+0.5870G+0.1140B$

The average method is the simplest algorithm which is based on the average of scaling values. While the lightness method average is a grayscale value that is defined by the most prominent and least prominent colours. The luminosity technique is an advanced variant of the Average method. In addition to averaging the values, a weighted average is created to cater to human perception. The weighted average method preserves the perceived brightness and contrast of the original colour image, resulting in a grayscale image that maintains visual fidelity. This method considers the distinct contributions of each colour channel to the overall luminance, which results in a more accurate representation of grayscale intensities. To complete this step, the method of weighted average is applied in order to find the grayscale value.

The grayscale value is utilised for determining the binary value of a binary image during the thresholding step. After the formation of a grayscale image, there is a process known as binarization that converts the grayscale image into a binary image, also referred to as a black-and-white image. During the binarization procedure, there are also two steps: thresholding and normalisation. In the normalisation step, a threshold value, T, is produced and used to determine the binary value of the black and white image in the thresholding process. Normalisation aims to remove all types of variations during writing, and standardised data is obtained [12]. As image processing is a continuous process, it is necessary to determine the standard size of the image during the scaling process in order to ensure stability for all analysed images. This means that scaling processes produce an image with standard dimensions that affect the values in image processing. These values include the RGB value, the grayscale value, and lastly, the binary value resulting from the thresholding process. Therefore, scaling processes play the most important role in ensuring that the result is consistent over time for all tested images.

The final step of image processing is thresholding, which is a process used to convert grayscale images into binary images. At this step, binary values are being generated. According to Bangare *et al.,* [11], thresholding is a method used to remove an intended object or target object from its background image. This is done by assigning a value of intensity T (threshold) to every pixel, categorising each pixel as either a background point or an object point. The process of thresholding, which is a continuation of his writing, involves a simple comparison. In this process, each pixel value in *f* is compared to a threshold value, T. At this stage, the image is classified into 0 and 1 based on the value of T that is compared with the grayscale of $f(x,y)$. These values represent black and white, respectively. The threshold value is used as a cutoff point in the classification of data. During this process, the threshold value determines the pixels into two groups of values based on whether the intensity of the colour values is greater than or equal to or less than the limit of T. In general, the thresholding value of an image is found by assuming that the range of intensity levels caused by objects of interest is different from the background. Initially, a threshold T is randomly selected based on the histogram analysis. The value of T is chosen from between two segments that separate the black and white points. Any point (x,y) in the image that $f(x,y)>T$ is called an object point. Finally, the segmented image, denoted by $b(x,y)$, is given by Eq. (1).

$$b(x,y)=\begin{cases}1 & f(x,y)\geq T\\ 0 & f(x,y)<T\end{cases} \tag{1}$$

In previous studies, the threshold value, T, was determined within the range of $0-255$, with a limitation value of $T=128$ [5,16,20].

$$b(x,y)=\begin{cases}1 & f(x,y)\geq 128\\ 0 & f(x,y)<128\end{cases} \quad (2)$$

Through comparison, if the pixel value is greater than or equal to 128, then the binary value one Eq. (1) represents white colour. However, if the pixel value is less than 128, then the binary value zero (0) represents the black colour. To complete the procedure through comparison, the threshold value must first be determined based on the grayscale image. In order to identify the threshold value, there are four different ways that can be applied. These include the global thresholding method, variable thresholding method, local or regional thresholding, and dynamic or adaptive thresholding method. Among these four methods, the global thresholding method, which is also known as Otsu's method, is preferred. This method gives satisfactory results when the numbers of pixels in each class are close to each other [11]. According to him, it is also the most referenced thresholding method because it directly operates on the grey level histogram. Therefore, it is fast and computes an optimised threshold value. One of many binarization algorithms, it automatically performs clustering-based image thresholding.

Otsu's method is a nonparametric and unsupervised method for automatic threshold selection in picture segmentation [21]. The method is quite general, simple, and straightforward. The procedure utilises the zeroth-order and first-order cumulative moments of the grey level histograms. It can also optimise the selected threshold value and maximise the separability of the classified binary value in grayscale. According to Otsu [21], an optimal threshold (or set of thresholds) is automatically and stably selected, not based on differentiation (such as a local property like a valley), but on integration (a global property) of the histogram. Otsu stated that the method suggested in this correspondence may be recommended as the simplest and most standard one for automatic threshold selection, which can be applied to various practical problems. The statement is also acknowledged by Bangare *et al.,* [11] as a simple and standard method for determining the value of *T*. They also recommend this method because it is practical for solving various problems related to thresholding values.

Therefore, based on the criteria of this method, this study proceeds to find the value of *T* by utilising the global thresholding method, known as Otsu's method. The reason for choosing this method is that MATLAB software applies this method to compute a global threshold T from grayscale images. The MATLAB software selects Otsu's method because it selects a threshold that minimises the interclass variance of thresholder black-and-white pixels. Through the process of this stage, the binary values of 0 and 1 for the binarization image of *tudung saji* is generated based on the comparison of the grayscale value of $f(x,y)$ with the value of T. The result is utilised as an input for feature extraction in the training of data and the classification of *tudung saji* patterns. The form of output from the final step of image processing is displayed in Table 1. In this table, the output is examined as a finite zero-one matrix.

Table 1
Binary value resulted from the thresholding process of Batik [18]

Pixel	1	2	3	4	5
1	1	1	1	1	1
2	1	0	0	0	1
3	1	0	0	0	1
4	1	0	0	0	1
5	1	1	1	1	1

2.3 Features Extraction and Classification

Feature extraction is an essential process for transforming data or any information into a more manageable and understandable format. In order to facilitate effective analysis, modelling, decision-making, classification, or recognition of information across a variety of disciplines, such as feature extraction needs to be identified in the pattern recognition process. The process depends on the characteristics or properties that are being studied. The extraction phase in feature extraction recognises the property of the object and then sends it for the next classification [22].

In this study, two features of a finite matrix are taken into consideration: the zero-one matrix and the symmetric matrix, S_n. The proposed feature extraction algorithm for forming the finite matrix depends on several factors: the size of the matrix (whether it is square or non-square), the values of its entries, and its symmetrical property. The zero-one matrix is formed from the binary value of the binarization image. The size of the matrix is determined by the size of the image *tudung saji* pattern, which has been modified through image processing. The matrix can be either square $n \times n$ or non-square $n \times m$. In order for a matrix to be considered symmetrical, it must satisfy the following properties.

i. Symmetric along the diagonal, $A = A^T$
ii. Real eigenvalues
iii. Eigenvectors corresponding to the eigenvalues are orthogonal.
iv. Symmetric matrices are always diagonalizable, $D = PA^{-1}P$

Image classification is the final result of a procedure in which the classification or recognition of input is based on the analysis of characteristics obtained from feature extraction.

3. Transforming Image of *Tudung Saji* Pattern into Zero-One Matrix

The technique of pattern recognition is utilised to generate the zero-one matrix for the *tudung saji* pattern. In this process, the image of the chosen *tudung saji* pattern serves as the input for data loading. The system comprises four main parts: data loading, image processing, feature extraction, and recognition or classification of selected patterns of *tudung saji*. According to previous studies [2] and [3], it has been stated that there is a relationship between group theory and graph theory in the context of the pattern of *tudung saji.* These studies provide a detailed discussion on the triaxial template of *tudung saji*. According to the triaxial template, the selected pattern of *tudung saji* is isomorphic to the symmetric group. Therefore, the discussion revolves around the concept of how pattern recognition functions, resulting in a zero-one matrix as an output. Subsequently, the obtained result is analysed in various stages to classify the pattern of *tudung saji* into group theory and graph theory.

The discussed *tudung saji* patterns are Pati Sekawan (Flock of Pigeon), Bunga Tanjung (Cape Flower), Butang (Buttons), Kapal Layar (Sailboats), and Jari Ketam (Crab Finger). The selected patterns are based on the same pattern from previous studies, which refer to [2,3,23]. To continue the study, the pattern recognition system worked as follows: The patterns of *tudung saji* are so diverse that nearly every region in Malaysia is involved in their making, including Melaka, Terengganu, and Kelantan. *Tudung saji* has many patterns and variations. Almost every *tudung saji* pattern from different regions has similar patterns, such as Pati Sekawan (Flock of Pigeons), Bunga Tanjung (Cape Flower), Butang (Buttons), Kapal Layar (Sailboats), Jari Ketam (Crab Finger), and so on [3]. This paper focuses on the study of the *tudung saji* pattern from the perspective of mathematical theory. It emphasises image processing for pattern recognition in order to classify the *tudung saji* pattern using a matrix form. The investigation and exploration of the information contained behind an image, in order to identify a pattern, is driven by artificial intelligence. The zero-one matrix, which is produced by image processing, is utilised in subsequent group theory analysis to learn how to categorise the *tudung saji* patterns into groups. This is done by using the image of triaxial template patterns of *tudung saji.*

3.1 Data Loading

The input data for data loading is the image of the *tudung saji* pattern, which is taken using a digital camera. Digital cameras come in a variety of brands, including Nikon, Canon, and others [24]. Any digital camera may be used, but with the distinction that each image captured is encoded in the same format, which is Joint Photographic Experts Group (JPEG). According to Amran *et al.,* [24], a few elements need to be considered in the accuracy of an image photoshoot, like the light condition, the use of a camera flash, and the camera resolution. The most important thing is the technique used to acquire the image. The image of *tudung saji* has been taken from a top-down view, resembling a plane view, in order to showcase the overall shape of *tudung saji*. Therefore, the cross section of *tudung saji*, as viewed from the top, is considered an input for image processing. A few images are used for the same pattern in order to ensure that the results are similar and accurate, or to ensure that the differences are not so significant.

3.2 Image Processing

The image processing involves several steps, namely scaling, grayscale conversion, and thresholding. These processes transform a regular image of *tudung saji* patterns into a binary image, which produces a binary value as the output. There exist three steps within this stage.

i. Scaling: the result is given for the RGB (red-green-blue) image value for each pixel, and the size of the image is reduced to a suitable dimension in order to find the RGB value. To obtain the proper image dimensions for determining the RGB value, it is necessary to perform resizing and reduction of the image size. In this study, several dimensions are taken into account for each image of the *tudung saji* pattern in order to ascertain the optimal size that accommodates all images in a standardised format, thereby ensuring consistent outcomes.
ii. Grayscale: the image undergoes the grayscale process where the resizing image becomes grey. At this stage, the grayscale value obtained replace the RGB value of each image by using weighted average method $f(x,y) = 0.2989R + 0.5870G + 0.1140B$, and it becomes the determinant for the production binary value through the process of thresholding. The grayscale value, which is the average value of RGB, is known as the grayscale value $f(x,y)$ and applied in the determination of the binary value during the thresholding step.
iii. Thresholding: greyish images are converted into binary images that are black and white images and give the binary value of 0 and 1. Through the comparison between $f(x,y)$ and threshold value, T , the binary value of the image is determined. The MATLAB software is used to complete the entire process. It is important to note that the threshold value varies between images because the original image's size is not uniform, and the RGB value and grayscale are also affected by the scaling and grayscale processes.

3.3 Feature Extraction

Some definitions and properties of the zero-one matrix are used to analyse image processing output. To proceed with the output classification, properties of symmetric matrices were also tested. The outcome prompts further discussion based on the need for further research.

3.4 Classification

The classification of each *tudung saji* pattern depends on the result obtained from feature extraction. The purpose of this study was to determine whether the pattern of *tudung saji* could be defined as a finite zero-one matrix and classified as a symmetry matrix, S_n. Further study is being continued in order to classify it into various theorems of group theory.

4. Significant of Pattern Recognition

In the present day, pattern recognition is a scientific field that is currently experiencing a surge in popularity. The application of pattern recognition has become a trend, and it is applied in many fields. These fields include Biometric devices, computer vision, E-commerce, and trend analysis for business, among others. Pattern recognition is seen as an important process for classification. According to Karyakarte and Savant [25], it plays an important role in various tasks such as reading texts, identifying people, retrieving objects, or finding the way in a city. Once patterns have been established, we are able to classify new objects or phenomena into a class of the known patterns. Through this study, we propose pattern recognition that establishes a connection between mathematics and art. The importance is listed as follows.

i. Determine and analyse the pattern of any work of art, such as *tudung saji*, within another domain of thought, such as mathematics.
ii. The classification of art is determined by unseen data, which is represented by a binary value.
iii. Recognised pattern in art using mathematical concepts' properties and characteristics.
iv. Significant role in the introduction of sciences and arts.

4. Conclusion

This article discusses the technique of pattern recognition in the classification of the *tudung saji* pattern. It focuses on converting the pattern into a zero-one matrix using binary values obtained from image processing. Based on the findings of this report, a method to extract the data from any picture (image) is highlighted as a means to relate the art with mathematical ideas. The mathematician can manipulate the result of image processing into various mathematical fields. In this case, we attempt to establish a connection between the outcome obtained from image processing and a finite zero-one matrix. The subsequent discussion focuses on the classification of the *tudung saji* pattern as zero-one matrices within the context of other ideas, such as group theory and graph theory. Therefore, exploring a new way to perceive the beauty of the arts within a mathematical context is a commendable decision. This review paper provides a potential method to extract the data of binarization image by using pattern recognition, in terms of contribution.

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References
[1] Adam, Noor. "Weaving culture and mathematics: An evaluation of mutual interrogation as a methodological process in ethnomathematical research." PhD diss., ResearchSpace@ Auckland, 2011. https://doi.org/10.1016/j.sbspro.2010.12.097
[2] Zamri, Siti Norziahidayu Amzee. "A Relation Between Tudung Saji Weaving Patterns and Group Theory." PhD diss., Universiti Teknologi Malaysia, 2015.
[3] Zamria, Siti Norziahidayu Amzee, Nor Haniza Sarmina, Noor Aishikin Adamb, and Atikah Mohd Sania. "Modelling of Tudung Saji Weaving Using Elements in Group Theory." *Jurnal Teknologi* 70, no. 5 (2014). https://doi.org/10.11113/jt.v70.3516
[4] Basu, Jayanta Kumar, Debnath Bhattacharyya, and Tai-hoon Kim. "Use of artificial neural network in pattern recognition." *International journal of software engineering and its applications* 4, no. 2 (2010).
[5] Andrian, R., B. Hermanto, and R. Kamil. "The implementation of backpropagation artificial neural network for recognition of batik Lampung motive." In *Journal of Physics: Conference Series*, vol. 1338, no. 1, p. 012062. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1338/1/012062
[6] Isola, Phillip, Jun-Yan Zhu, Tinghui Zhou, and Alexei A. Efros. "Image-to-image translation with conditional adversarial networks." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 1125-1134. 2017. https://doi.org/10.1109/CVPR.2017.632
[7] Davies, E. Roy. *Computer vision: principles, algorithms, applications, learning*. Academic Press, 2017.
[8] Bhamare, Devyani, and Poonam Suryawanshi. "Review on reliable pattern recognition with machine learning techniques." *Fuzzy Information and Engineering* 10, no. 3 (2018): 362-377. https://doi.org/10.1080/16168658.2019.1611030
[9] Li, Linyu, Zichun Chen, and Xiaowei Jiang. "A Hybrid Picture Fuzzy Similarity Measure and Improved VIKOR Method." *International Journal of Computational Intelligence Systems* 15, no. 1 (2022): 113. https://doi.org/10.1007/s44196-022-00165-7
[10] Singh, Chetanpal. "Machine Learning in Pattern Recognition." *European Journal of Engineering and Technology Research* 8, no. 2 (2023): 63-68. https://doi.org/10.24018/ejeng.2023.8.2.3025
[11] Bangare, Sunil L., Amruta Dubal, Pallavi S. Bangare, and Suhas Patil. "Reviewing Otsu's method for image thresholding." *International Journal of Applied Engineering Research* 10, no. 9 (2015): 21777-21783. https://doi.org/10.37622/IJAER/10.9.2015.21777-21783
[12] Mustafa, Wan Azani, Haniza Yazid, and Mastura Jaafar. "A systematic review: Contrast enhancement based on spatial and frequency domain." *Journal of Advanced Research in Applied Mechanics* 28, no. 1 (2016): 1-8.
[13] Omarov, Batyrkhan, and Young Im Cho. "Machine learning based pattern recognition and classification framework development." In *2017 17th International Conference on Control, Automation and Systems (ICCAS)*, pp. 1-5. IEEE, 2017. https://doi.org/10.23919/ICCAS.2017.8204282
[14] Zhu, Yubin, Yonghang Dai, Kaining Han, Junchao Wang, and Jianhao Hu. "An efficient bicubic interpolation implementation for real-time image processing using hybrid computing." *Journal of Real-Time Image Processing* 19, no. 6 (2022): 1211-1223. https://doi.org/10.1007/s11554-022-01254-8
[15] Boukhtache, Seyfeddine, Benoit Blaysat, Michel Grediac, and Francois Berry. "Alternatives to bicubic interpolation considering FPGA hardware resource consumption." *IEEE Transactions on Very Large Scale Integration (VLSI) Systems* 29, no. 2 (2020): 247-258. https://doi.org/10.1109/TVLSI.2020.3032888
[16] Li, Yingmin, Feifei Qi, and Yi Wan. "Improvements on bicubic image interpolation." In *2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, vol. 1, pp. 1316-1320. IEEE, 2019. https://doi.org/10.1109/IAEAC47372.2019.8997600
[17] Pebrianasari, Vera, Edy Mulyanto, and Erlin Dolphina. "Analisis Pengenalan Motif Batik Pekalongan Menggunakan Algoritma Backpropagation." *Techno. Com* 14, no. 4 (2015): 281-290.
[18] Saravanan, C. "Color image to grayscale image conversion." In *2010 Second International Conference on Computer Engineering and Applications*, vol. 2, pp. 196-199. IEEE, 2010. https://doi.org/10.1109/ICCEA.2010.192
[19] Rabab, Miss, Abd Al-Rasool, and Muthana Hachim. "Digital Image Processing Lab." 2015.
[20] Zaimi, Ainin Najiha, Siti Nurafifah Azman, Syarifah Maisarah, Ilya Syed Hasan, and Masnira Ramli. 2022. "Detection of Similarity in Batik Motifs Using Backpropagation Method." *Mathematics Letters*. Vol. 1.
[21] Otsu, Nobuyuki. "A threshold selection method from gray-level histograms." *IEEE transactions on systems, man, and cybernetics* 9, no. 1 (1979): 62-66. https://doi.org/10.1109/TSMC.1979.4310076

[22] Veena, S., T. Shankari, Senthil Sowmiya, Mundhra Varsha, Chennai Thiruverkadu, and Chennai Thiruverkadu. "A Survey on Tools Used For Machine Learning." *International Journal of Engineering Applied Sciences and Technology* 4, no. 9 (2020): 116-119. https://doi.org/10.33564/IJEAST.2020.v04i09.012
[23] Zamri, Siti Norziahidayu Amzee, Nor Haniza Sarmin, Noor Aishikin Adam, and Atikah Mohd Sani. "A Graph Theory Analysis on the Elements of Triaxial Template of Tudung Saji." *Menemui Matematik (Discovering Mathematics)* 36, no. 1 (2014): 1-8.
[24] Amran, Muhammad Syahiran, and Khairul Nizam Tahar. "Assessment on different digital camera calibration software for photogrammetric applications." *Journal of Advanced Research in Applied Mechanics* 30, no. 1 (2017).
[25] Karyakarte, Susmita, and Ila Savant. "Pattern Recognition Process, Methods and Applications in Artificial Intelligence." *Pattern Recognition* 6, no. 11 (2019).

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