Generating of North Sumatran Songket Fabric Motifs Based on Crystallographic Groups Using MATLAB GUI

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Abstract. Traditional clothing is a cultural heritage that should be preserved and expanded upon. Traditional fabrics that were once only used at traditional events are now catching the attention of the fashion industry. As a result, various innovations are developed to help traditional fabrics sell well in today's market. The concept of crystallographic groups is one of the innovations that can be used to develop motifs or patterns. Crystallographic groups are a mathematical classification of two-dimensional repeating patterns that are based on symmetry. Patterns like this are common in architecture and decorative arts, particularly in textiles, tiles, and wallpaper. In this study, the authors generated North Sumatran songket motifs based on 11 crystallographic group patterns using the MATLAB GUI program. The findings of this study can be used as a resource for art activists developing fabric motifs in the future.

Keywords: crystallography, symmetry, traditional cloth, songket

1 Introduction

North Sumatra is one of the provinces with the most diverse cultures. Beginning with dances, dwellings, weapons, tribes, languages, and traditional textiles. North Sumatra has woven fabrics with beautiful and distinctive patterns, such as the North Sumatran Malay songket, when discussing traditional fabrics. This woven fabric should be preserved and developed as a cultural heritage. However, community support to promote the production of traditional fabrics in North Sumatra is lacking. This is evidenced by the decline in buying and selling of Ulos cloth in Tarutung in 2021, which has impacts for the well-being of weavers [14]. Obviously, this problem requires immediate attention. Chairman of the Regional National Crafts Council (Dekranasda) of North Sumatra, Nawal Lubis, proposed that district/city governments require the use of official attire woven from materials typical to each region and produced by craftsmen. During his visits to various districts and cities in North Sumatra, he observed that all regions possess woven fabrics with distinctive motifs and colors [16].

ICIESC 2022, October 11, Medan, Indonesia

DOI 10.4108/eai.11-10-2022.2325312

As time progresses, the fashion industry is beginning to recognize traditional fabrics that were once only worn at traditional events. Edward Hutabarat, the senior designer, incorporates Ulos into Manhattan's contemporary fashion style [12]. In addition, a number of micro, small, and medium-sized enterprises are aggressively innovating woven fabrics to make them more fashionable and trendier in order to attract millennials. Mathematical concepts are used to create cloth patterns that are still relatively unknown to the public. Symmetric group theory is a mathematical concept that can be used to develop motifs or patterns. A symmetric group is one whose elements are all bijections of the set to itself, with the operation being a composition function [17]. The symmetry group structure is applicable in both two- and three-dimensional forms. This structure can be used to create fabric patterns in the flat plane in the future.

The crystallographic group is one of the two-dimensional symmetry groups. A crystallographic group, or sometimes called a wallpaper group, is a mathematical classification of a two-dimensional repeating pattern, based on the symmetry in the pattern. These patterns are prevalent in architecture and the decorative arts, particularly in textiles, tiles, and wallpaper. [18] provides a more comprehensive examination of crystallographic groups. In a plane, there are 17 crystallographic groups that result from infinitely repeated patterns [3]. From the seventeen distinct patterns, specific periodic patterns can be determined. In the periodic pattern plane, there are five lattices: parallelograms, rectangles, squares, rhombuses, and hexagons. **Table 1** shows the representation of the 17 crystallographic group patterns.

Table 1. Identification chart for plane periodic pattern [3]

Type	Lattice	Highest Rotation Order	Generating Region	Reflections	Non-trivial Sliding Reflections
$p1$	Parallelogram	1	1 unit	No	No
$p2$	Parallelogram	2	$\frac{1}{2}$ unit	No	No
pm	Rectangular	1	$\frac{1}{2}$ unit	Yes	No
pmg	Rectangular	2	$\frac{1}{4}$ unit	Yes	Yes
pgg	Rectangular	2	$\frac{1}{4}$ unit	No	Yes
cmm	Rhombic	2	$\frac{1}{4}$ unit	Yes	Yes
$p3$	Hexagonal	3	$\frac{1}{3}$ unit	No	No
$p3m1$	Hexagonal	3	$\frac{1}{6}$ unit	Yes	Yes
$p31m$	Hexagonal	3	$\frac{1}{6}$ unit	Yes	Yes
pg	Rectangular	1	$\frac{1}{2}$ unit	No	Yes
cm	Rhombic	1	$\frac{1}{2}$ unit	Yes	Yes
pmm	Rectangular	2	$\frac{1}{4}$ unit	Yes	No
$p4$	Square	4	$\frac{1}{4}$ unit	No	No
$p4m$	Square	4	$\frac{1}{8}$ unit	Yes	Yes
$p4g$	Square	4	$\frac{1}{8}$ unit	Yes	Yes

Type	Lattice	Highest Rotation Order	Generating Region	Reflections	Non-trivial Sliding Reflections
$p6$	Hexagonal	6	$\frac{1}{6}$ unit	No	No
$p6m$	Hexagonal	6	$\frac{1}{12}$ unit	Yes	Yes

Several studies on generating symmetrical group patterns have been conducted, including [7], who manually produced 13 stamped batik motifs using crystallographic groups. Through repeated tastings, the application of group theory of symmetry and two-dimensional crystallography, particularly the geometric transformation of a flat plane (the basic motif with the theme of crop circles), can produce a symmetrical motif of stamped batik and its various patterns. The entire procedure of stamping batik is a creative, innovative, and effective educational medium. Then Nataliani et al. [9] studied how a group of wall paper could be used to produce repetitive and symmetrical motifs on textiles, ceramics, and other materials. Using one or more groups of wallpaper, the motif can consist of a single or multiple basic patterns. This study developed motifs based on the basic spiral pattern. In addition, studies on the existence of symmetrical group patterns in traditional fabrics can be seen in [4], [11], and [19].

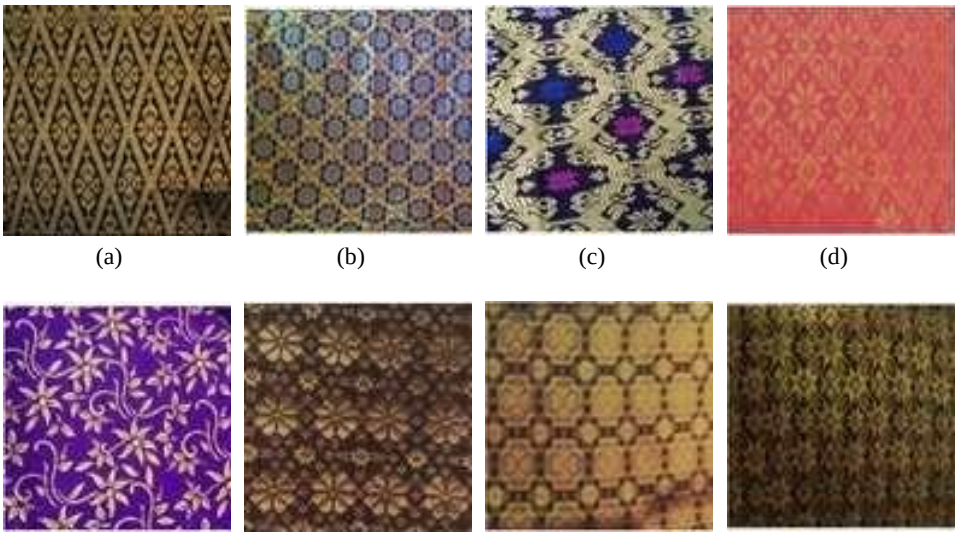
Based on the crystallographic group pattern, the North Sumatran songket motif was generated for this study. Using the the MATLAB program simplifies the procedure. According to Noviansyah [10], MATLAB is a programming language that was designed to facilitate complex calculations or simulations of a system being simulated. The display program used for motif generation is a graphical user interface. This is intended to make it look more efficient and attractive [8]. Numerous studies on the creation of fabric motifs using computer programs have been conducted. Using Maple-13, Anggraini [2] created the Banyuwangi batik motif based on fractal geometry and geometric transformation. Hapsari and Haryono developed basic motifs taken from batik motifs (Kawung, Parang Rusak, Truntum) by utilizing the gene phenotype of parameter values using mathematical computations [5]. In addition, Abu et al. [1] created the Taiganja batik motif in 2021 by adding parameters in the form of rotation parameters and redesigning the previous motif's background color using the MATLAB program.

2 Research Methods

This research consists of several stages, including:

1. Determining the basic pattern of generating North Sumatra songket motif.
   At this stage, the basic pattern of North Sumatra songket is determined, from which new motifs will be developed. The determination is based on the results of the analysis of crystallographic groups on North Sumatran songket fabric that has been carried out by Kartika et al. [6] in 2022. According to the results of the analysis, the North Sumatran songket motif contains five crystallographic group patterns. The MATLAB program will generate this basic pattern based on the crystallographic group pattern. In this study, a new motif will be created based on the eight fabric motifs depicted in **Figure 1**, which are

derived from the Batubara Malays and Langkat Malays, which are tribes from the province of North Sumatra.



(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 1. Some of the North Sumatran songket motifs, (a) *Pulut Manis*; (b) *Bunga Mawar* (Roses); (c) *Bunga Anggrek* (Orchids); (d) *Bunga Cempaka* (Champak Flower); (e) *Bunga Kenanga* (Ylang Flower); (f) *Tampuk Manggis*; (g) *Tolap Penuh*; (h) *Tolap Berantai*. [13],[15]

2. MATLAB GUI interface design
   At this stage the MATLAB GUI program is designed. The basic patterns that have been determined in stage (1) are put into the program. In addition, buttons for generating motifs according to the crystallographic group pattern are also inserted.

3. Generating basic patterns based on crystallographic group.
   After the MATLAB GUI program has been designed, the important process is generating the basic patterns into new motifs based on crystallographic groups. The resulting new motifs will be analyzed again in order to produce different motives.

3 Result and Discussion

This section describes the display of the MATLAB GUI program and the generation of North Sumatran songket motifs in subsections 3.1 and 3.2, respectively.

3.1 MATLAB GUI for North Sumatra Songket Motif Generation

To make it easier to generate songket motifs, a program was made using a GUI in MATLAB. In this program the basic pattern is generated by applying the crystallographic group. The program interface is shown in **Figure 2**.

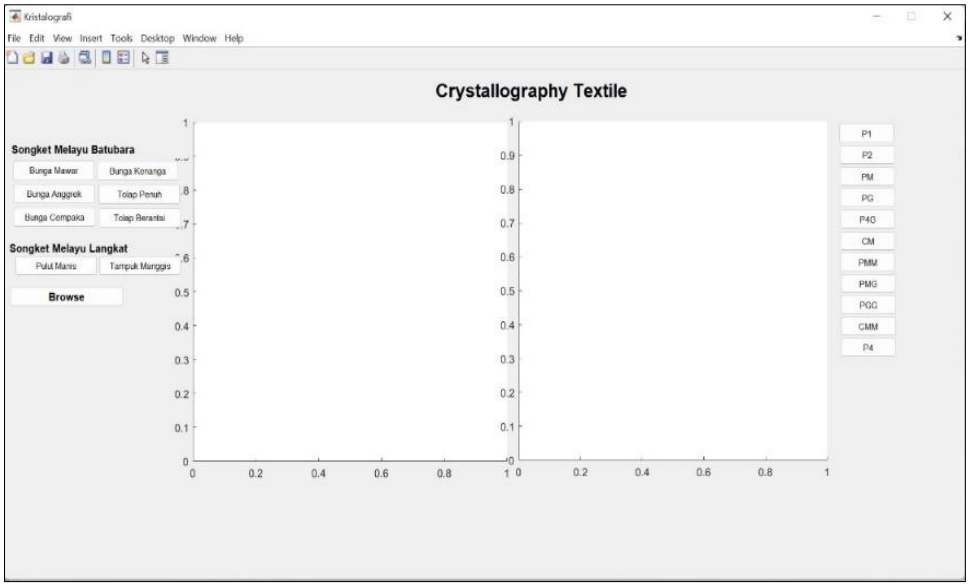


Fig. 2. MATLAB GUI interface for songket motif generation

In **Figure 2**, it can be seen that there are several types of North Sumatran songket. In the middle, there are two screens. If you choose one type of songket, the screen will display the songket motif and the basic pattern that will be generated as shown in **Figure 3**.

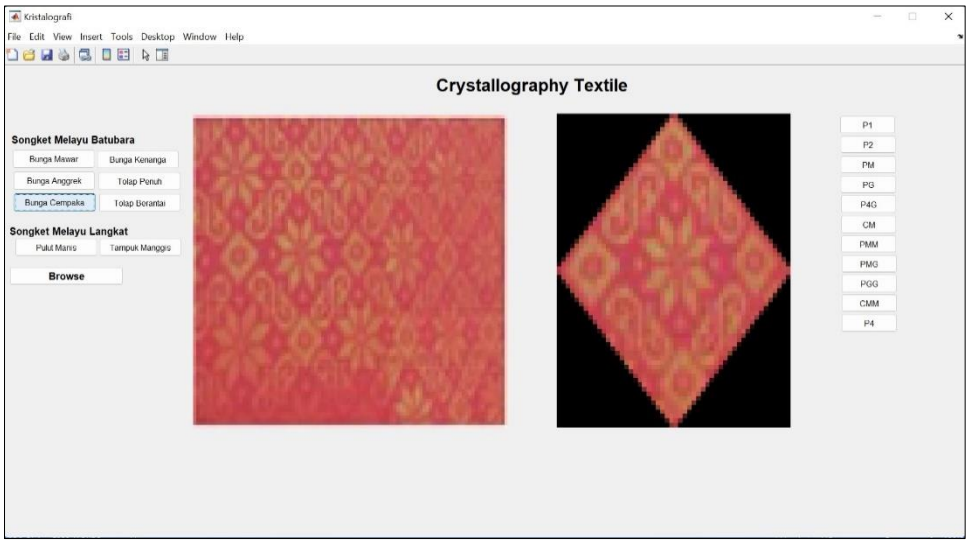


Fig. 3. MATLAB GUI for full Champak Flower motif generation

You can use the "Browse" button to generate fabric motifs other than those displayed on the screen. This button is used to search for motifs in the device. Additionally, the most important buttons are those used to generate patterns based on crystallographic groups. This button is

located on the right side. **Figure 2** illustrates that eleven buttons are available from the seventeen patterns of the existing crystallographic groups. The eleven crystallographic groups are $p1, p2, pm, pg, p4g, cm, pmm, pmg, pgg, cmm$ and $p4$. There are six crystallographic group patterns that cannot be used in this program to generate patterns. This is because the image's basic pattern is converted into a square matrix. Therefore, the crystallographic group with a hexagonal lattice cannot be processed correctly. **Figure 4** depicts one of the new motifs generated by this program.

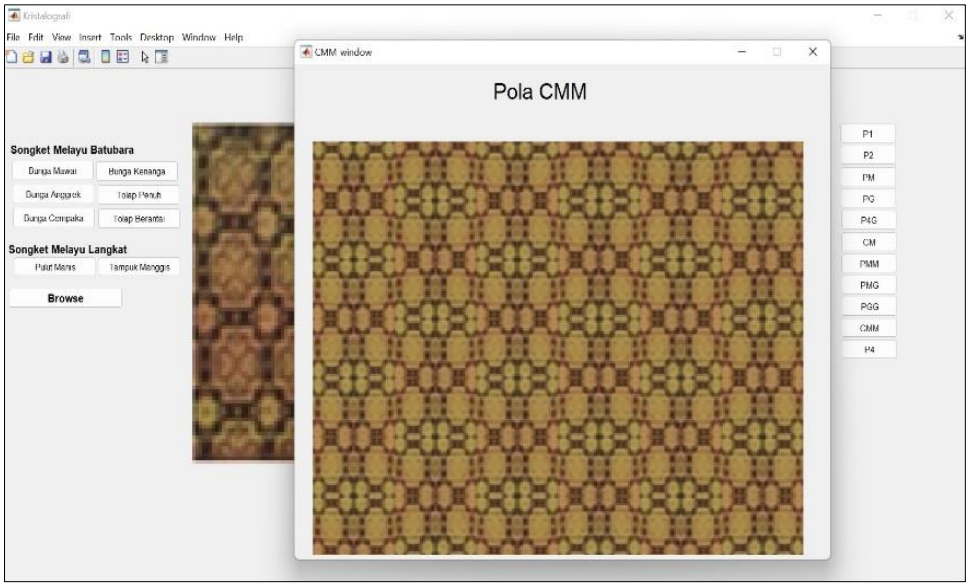


Fig. 4. One of the result of motif generation using MATLAB GUI

Figure 4 shows the results of the *Tolap Penuh* motif generation based on the *cmm* pattern in the crystallographic group. The *cmm* pattern is a crystallographic group pattern formed from the results of two-way reflection and two-way translation. The *cmm* pattern has a rhombus lattice.

3.2 Generating North Sumatran Songket Fabric Motifs

1. *Pulut Manis* Motif
   This Langkat Malay songket symbol represents the culinary characteristics of the Langkat region, namely sweet rice, which is also the name of the symbol (pulut manis). Why pulut manis is applied to the Langkat Malay songket is because it is said that every Langkat Malay event must include sweet rice because it is delicious and easy to prepare as a typical food of the Langkat Malay region [15]. The *Pulut Manis* motif has a *pmm* crystallographic group based on analysis in [6]. Thus, the *Pulut Manis* motif is formed by horizontal and vertical translation and reflection in two directions. This motif features a rectangle lattice. **Figure 5** depicts the basic pattern generation of *Pulut Manis* motif using the MATLAB GUI.

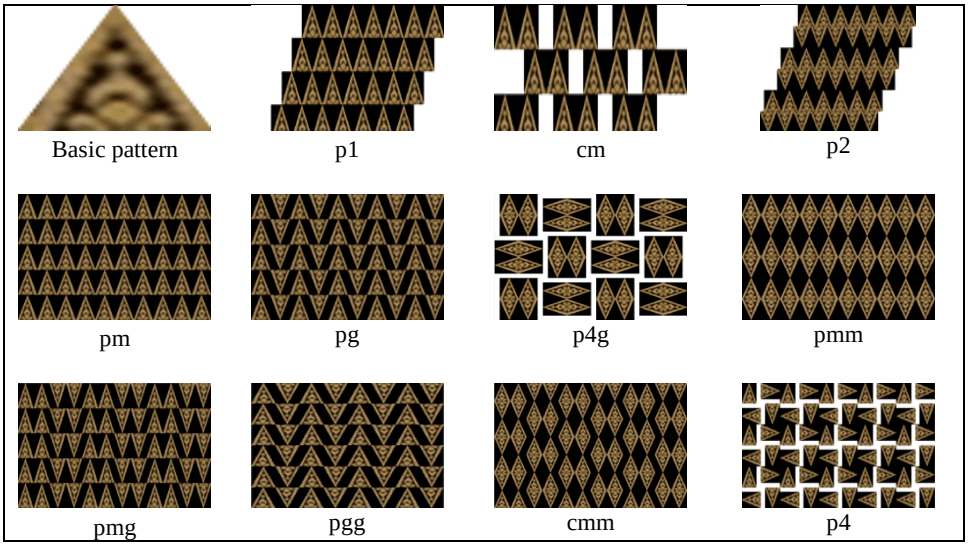


Fig. 5. Basic pattern and result of MATLAB GUI generation based on crystallographic group for *Pulut Manis* motif

2. *Bunga Mawar* Motif (Roses)

Roses are the preferred type of flower among the residents of Batubara. The philosophical meaning of this rose motif is a symbol of love or affection, romance, friendship, and peace [13]. According to [6], the rose motif has a $p4m$ crystallographic group pattern. This means that the rose motif is formed from the results of reflection, 90° rotation and two-way translation. This pattern has a square lattice. **Figure 6** depicts the generation of the rose motif's basic pattern using the MATLAB GUI.

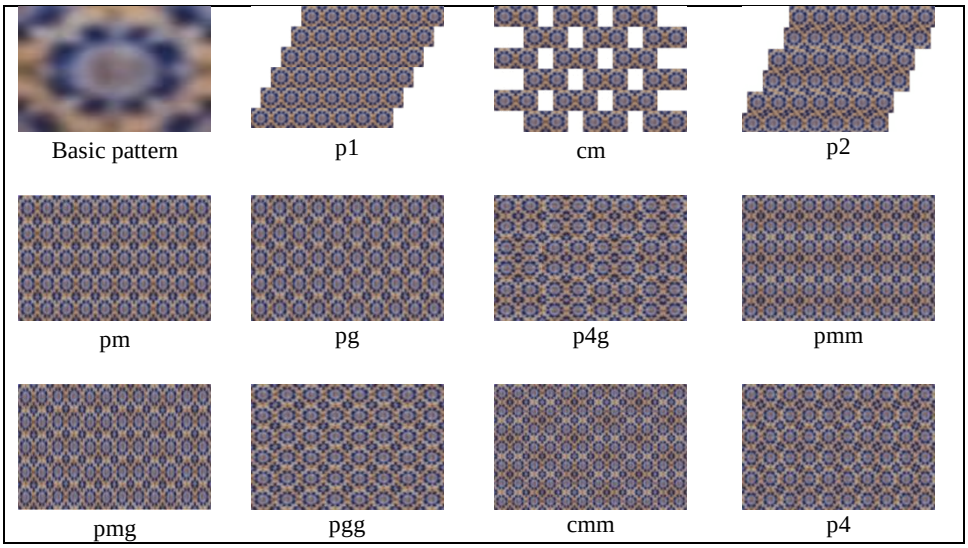


Fig. 6. Basic pattern and result of MATLAB GUI generation based on crystallographic group for *Bunga Mawar* motif

3. *Bunga Anggrek* Motif (Orchids)
Orchid flowers differ from other flowers in that the crown takes a long time to reveal. Many people like this flower because of its beauty and durability. This is a difficult flower to grow and one that requires patience, as orchids take years to bloom. The philosophical significance of the orchid flower motif is patience in pursuing a dream [13]. The motif has a $p4g$ crystallographic group pattern according to [6]. This means that the orchid flower motif is formed from the result of shear reflection, 90° rotation and two-way translation. This pattern has a square lattice. **Figure 7** depicts the generation of the basic pattern of the orchid flower motif using the Matlab GUI.

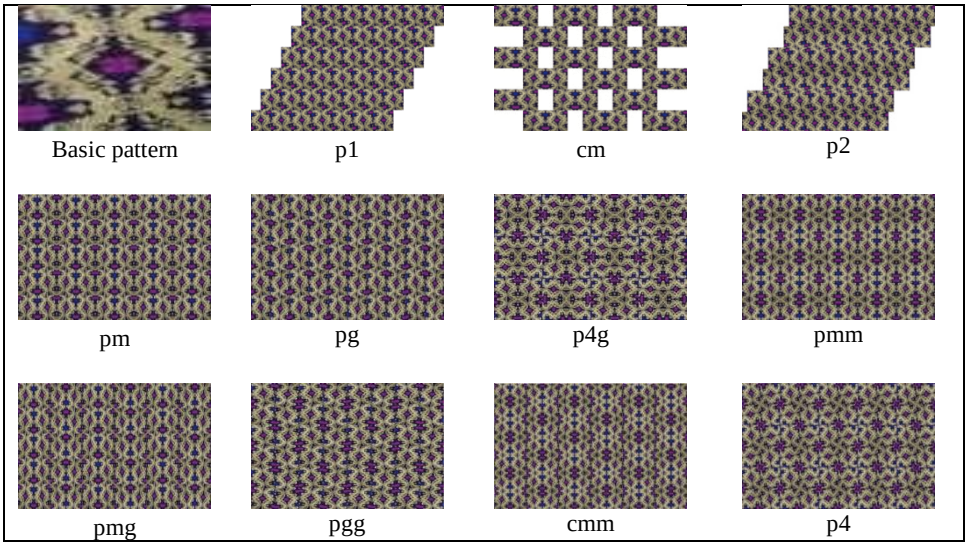


Fig. 7. Basic pattern and result of MATLAB GUI generation based on crystallographic group for orchid flower motif

4. *Bunga Cempaka* Motif (Champak Flower)
This *Cempaka* motif is the motif most favored by Batubara songket customers. *Cempaka* means to stick together or to join. *Cempaka* flowers wrapped in betel leaves are thrown by the groom to the bride during the "throwing betel" ceremony at a traditional Malay wedding ceremony. The intent is for the woman to be loyal to her husband and vice versa. Champaca flowers are also used to fragrance the bridal bed and can be used to make buns. Champaca flowers, as well as roses, jasmine flowers, and other flowers, are required to complete the potpourri. This champaca flower is a type of kantil flower; its shape is similar to that of cananga flowers, but cananga is longer and greener, whereas chrysolite comes in a variety of colors, including yellow, white, and blue. The philosophical significance of the *Cempaka* flower is the diversity that exists in Batubara, including the variety of marine, vegetable, religious, ethnic, and cultural groups that coexist in perfect harmony [13]. According to [6], the *Cempaka* flower motif has a pmm crystallographic group pattern. In other words, the *Cempaka* flower motif is the result of two-way reflection and two-way translation on a rectangular or square lattice. The generation of the basic pattern of the *Cempaka* flower motif using the MATLAB GUI is shown in **Figure 8**.

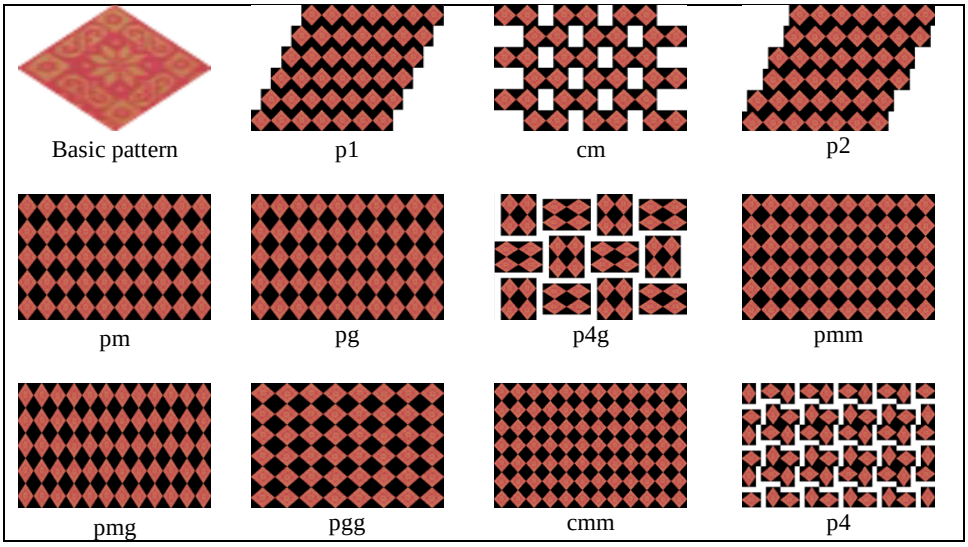


Fig. 8. Basic pattern and result of MATLAB GUI generation based on crystallographic group for *Cempaka* flower motif

5. *Bunga Kenanga* Motif (Ylang Flower)

Ylang flowers have a distinct aroma and is commonly referred to as the perfume tree. This ylang flower is frequently used as a shade in the yard or along the side of the road by sowing flowers and the tree. The ylang flower motif's philosophical significance is fragrance [13]. The ylang flower motif has a $p1$ crystallographic group pattern according to [6]. This means that this motif is formed from the results of two-way translation. **Figure 9** depicts the generation of the basic motif of the ylang flower using the MATLAB GUI.

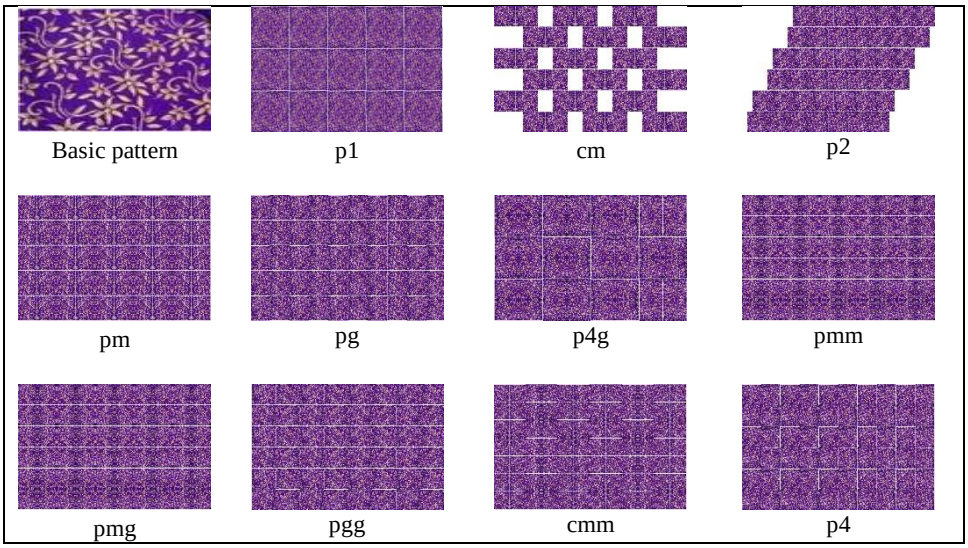


Fig. 9. Basic pattern and result of MATLAB GUI generation based on crystallographic group for ylang flower motif

6. *Tampuk Manggis* Motif

In ancient times, the fertile soil of Batubara district was overgrown with a variety of fruits, including mangosteen. The mangosteen tree is now rare and almost extinct. The crown of the mangosteen fruit, which used to flourish, is realized in the Batubara songket motif. The philosophical significance of *Tampuk Manggis* is majesty and glory [13]. According to [6], the crystallographic group pattern of the *Tampuk Manggis* motif is *cmm*. This indicates that the motif of *Tampuk Manggis* is the result of two-way reflection and two-way translation on a square unit lattice. **Figure 10** depicts the basic pattern generation of the *Tampuk Manggis* motif using the MATLAB GUI.

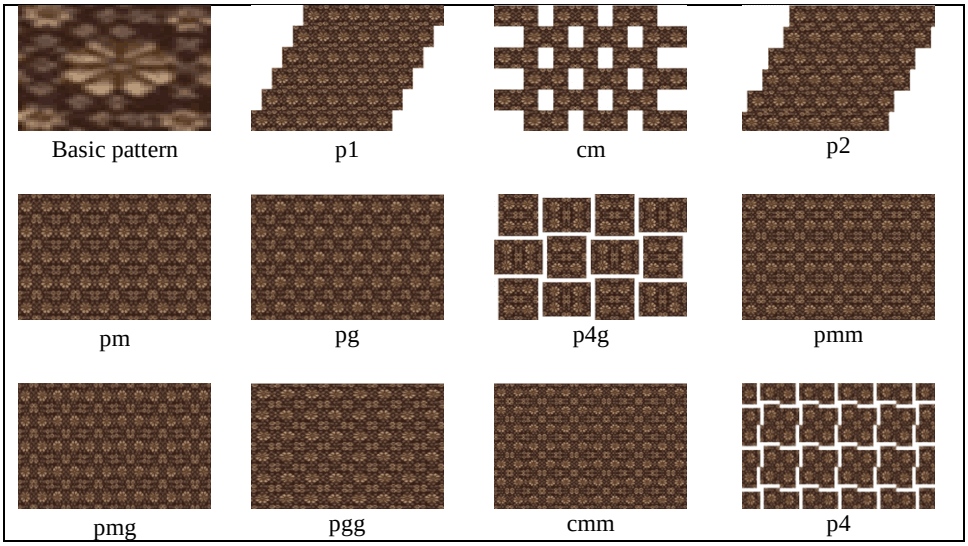


Fig. 10. Basic pattern and results of MATLAB GUI generation based on crystallographic groups for the *Tampuk Manggis* motif

7. *Tolap Penuh* Motif

This *Tolap Penuh* motif was inspired by the bright light of the stars in the night sky; therefore, this tolap motif, which means shining, was created [13]. The *Tolap Penuh* motif with star motifs is fully woven on the fabric's surface. Majesty is the philosophical meaning of this *Tolap Penuh* motif. The motif's shining star in the sky represents the majesty of imagination. According to [6], the crystallographic group pattern of the *Tolap Penuh* motif is $p4m$. This means that the *Tolap Penuh* motif is formed from the result of reflection, 90° rotation and two-way translation with the lattice being a square. **Figure 11** depicts the generation of the basic pattern of the *Tolap Penuh* motif using the MATLAB GUI.

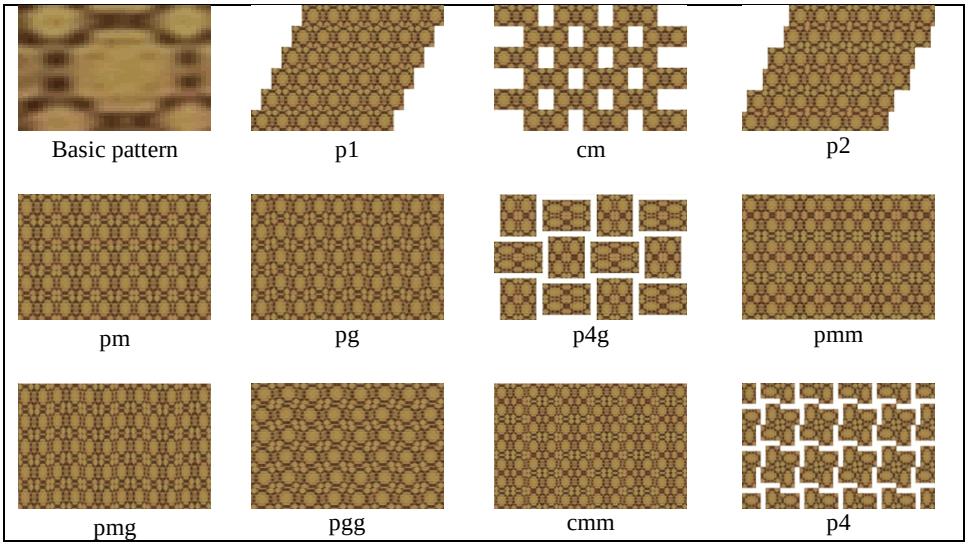


Fig. 11. Basic pattern and result of MATLAB GUI generation based on crystallographic group for *Tolap Penuh* motif

8. *Tolap Berantai* Motif

The philosophical significance of this motif is unity [13]. According to [6], the crystallographic group pattern of the *Tolap Berantai* motif is $p4m$. This means that the *Tolap Berantai* motif is formed from the result of reflection, 90° rotation and two-way translation. **Figure 12** depicts the generation of the basic pattern of the *Tolap Berantai* motif using the MATLAB GUI.

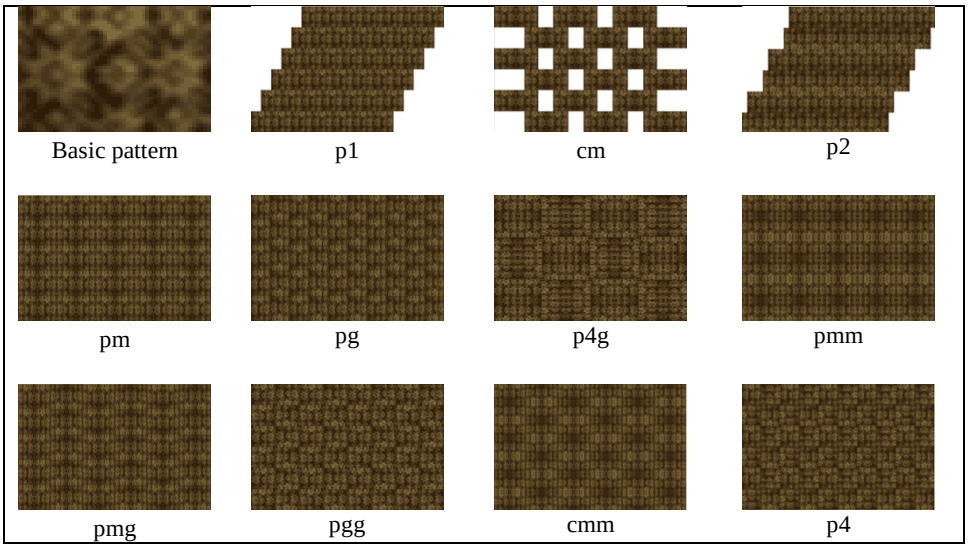


Fig. 12. Basic pattern and result of MATLAB GUI generation based on crystallographic group for *Tolap Berantai* motif

4 Conclusions

In this study, a MATLAB program with a graphical user interface was developed to generate motifs based on crystallographic group patterns. This research produced 76 new motifs derived from the North Sumatran songket motif.

Acknowledgments. The authors would like to thank the Institute for Research and Community Service (LPPM) of Universitas Negeri Medan for providing financial assistance through the 2022 Public Service Agency funds.

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