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Natural Volatiles &
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Analysis of Frieze Patterns Concepts in *Pua Kumbu*

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Abstract: A traditional practice of the Iban from Sarawak, *Pua Kumbu* is a form of textile which is famous for its beauty. There is a general appreciation of how it is exquisitely designed and patterned. It has been recognised by analytical studies that *Pua Kumbu* designs use transformational geometrical shapes in the frieze. This paper explores the geometry elements that have been portrayed in the form of different flora and fauna motifs. The examples of mathematical ideas in motifs produced by weavers in Sarawak have been analysed through this study. Although it is still in the form of preliminary observations, it has been revealed that the principles of geometry, such as enlargement, reflection, rotation, and translation are often used in the *Pua Kumbu* patterns. This woven art by the Ibans indirectly applies the principles of geometry in the form of beautiful and high-value motifs. This paper may benefit this field and the professionals related to it to act as a useful guideand also may serve as a point of reference for future studies on the unique patterns and designs of *Pua Kumbu*. The study also suggests that patterns based on geometry and symmetry exist in the ways *Pua Kumbu* is created.

Index Terms: *Pua Kumbu,* weaving, mathematical concepts, frieze patterns

1. Introduction

The objective of this paper is to explore the geometry elements that have been portrayed in the form of different flora and fauna motifs, commonly used in *Pua Kumbu* patterns. Besides that, this paper aims to explore the examples of mathematical ideas which exist in motifs produced by weavers in Sarawak. The way mathematics and culture are related can be expressed through ethnomathematics. A term referring to aparticular sociocultural context,where it encompasses linguistic, symbolic, physical, and behavioural characteristics. It also refers to traits of jargon and codes, as well as value and belief systems.

Mathematics is used abundantly in the songket weaving process, but a weaver is not conscious of the principles of mathematics that underlie it[1]. In this study, the mathematical thought patterns of those engaged in the songket weaving process are discussed, while various fundamental concepts of mathematics are identified. These include the processes of transforming, measuring, and estimating, as well as the need for the end product to be accurate and equal. The findingsare applied to *Pua Kumbu* as the outcome of an attractive, traditional Iban form of craftsmanship, in which mathematics is used in the *Pua Kumbu* weaving process.

1.1. Mathematics and Art

A common philosophical belief is that mathematics allows us to perceive the balance and attractiveness of our surroundings. It could be argued that there is a close connection between mathematical and artistic principles because symmetry is considered an ideal among mathematicians, although the concept itself is an approximation[2]. Embong expressed a similar view, outlining how a natural object like a human, an animal, a tree, a flower, or a leaf frequently displays symmetry [2]. In the artistic and natural context, it is possible to discover beauty through approximate symmetry, rather than in the clarity of symmetry[1].

1.3. Iban Motifs

The manner in which motifs are obtained for use in this Iban craft shows how intimate the connection is that these indigenous people have with the natural world of the Bornean forest. In the Iban culture, their way of life relies very much on nature to fulfil their needs. Therefore, in Iban motifs, the features and attributes in the design frequently adopt the natural forms on which their beliefs are based. In the Iban social culture, both import and purpose are attributed to certain plants, creatures, and other objects with symbolism. A fundamental subject can be identified in an Iban motif, which may contain a repertoire of items and images that are generally depicted simply as abstracts.Animals that are legendary or real yet anamorphic that are normally represented as dragons, hornbills, dogs, and roosters. The creature may also be an amphibian, a crustacean, or a reptile. The motifs may be floral or plant-based with wild ferns or flowers, celestial or cosmic with stars, moons, suns or clouds, or a supernatural being such as a giant, a ghost or an ancestor's picture. In Iban motifs, other key features by which to identify them are the swirls, spirals, and entities that often interlope or become entangled. Iban cloth-making and basket weaving also

makes extensive use of similar geometry, angles, and curls[3].

1.3. Pua Kumbu Design Motifs

Pua Kumbu is the most popular textile made of woven cotton by the Iban people of Sarawak. The majority of *Pua Kumbu* motifs contain anthropomorphism, zoomorphism, or symbolism linked to various plants and patterns of geometry. There is a belief that only an Iban tribal chief's wife or daughter may weave motifs containing humanoids or anthropomorphism (engkaramba). In addition to the latter type of motifs, fauna, flora, and the daily life activities of the Iban are also frequently depicted. These design motifs may be detailed or simpler and are classified as motifs of zoomorphism. Such an image may also appear to be a bird, a deer, a lizard, a crocodile, or a snake[4]. It was reported that several other illustrations of zoomorphic motifs include leeches, spiders, and centipedes [4]. Moreover, widely used motifs show various flora like rattan, creepers, trees of life, fruit, and flowers, as well as areas in which rice is grown and rice itself. In the patterns of geometry, a popular feature might be an abstract hook, scroll, lozenge, or hooked diamond [4]. The complex nature of the motif's design is represented by the way the forms of geometry are combined, which has a natural influence and an interpretation that is based on the intentions and symbolic understanding of the weavers[6].

The Iban people were generally animists and worshipped supernatural powers. Today, however, in terms of religion and faith, the Iban can be divided into two main groups, namely, those who embrace the world religions, particularly Christianity and Islam, and those who still follow their ancestral religion and beliefs that have been practiced since ancient times. The traditional Iban beliefs include belief in the existence of the supernatural world and supernatural powers comprising *petara* (gods), deities, *antu* (ghosts), good and evil spirits, and the spirits of their long-deceased ancestors. The Iban people believe that *petara* are the creators of the physical world and the spirit world and of all the inhabitants of the universe, which are referred to as living forms (including humans) and non-living forms.

In the Iban community, there is a type of woven fabric known as *kain pua*. *Kain* means 'cloth', while the word *pua* means 'blanket'. *Kain pua,* therefore, means 'blanket cloth'. Kain pua holds a very important and special place in the Iban community of Sarawak. Representing the heart of Sarawak Iban culture are the hand-woven textiles of the *Pua Kumbu*.*Kain pua* is considered a symbol of identity of the Iban people, whether in relation to one Iban and another or between the Iban and their *petara* (god) or other supernatural powers. Kain pua has a relationship with the supernatural or occult powers, and this is the main unique feature of the Iban culture. Thus, the manufacture of *kain pua* is always made accordingto the full ritual; in other words, the making of *kain pua* must be accompanied by certain rituals. The skills and expertise in *pua* weaving is considered a symbol of high social status among women in the Iban community. Specific rituals were established relating to the status change of the Iban woman as measured by her skills and expertise with which they weave the *pua*. *Kain pua* is a special object that is bound to all aspects of life in the Iban community, and is an important element connecting the Iban people with the supernatural powers and the spirit world. *Belia, Rakup,* and *Laletan* are the equipment used to produce *Pua Kumbu*. In the Iban culture, *Pua Kumbu* is a sacred object which is important during the *Miring* ritual. The *Miring* ritual is a performance where offerings are made to their gods. Without the *Pua Kumbu*, the offerings will not be accepted by their gods. *Pua Kumbu* is therefore an Iban icon, a symbol of Iban identity and heritage in Sarawak.

If a *Pua Kumbu* is well-made, this indicates not only the ability and proficiency of the weaver in her craft, but alsorepresents the inner self and its condition. The basic features of the *Pua Kumbu* comprise two cloth pieces that are connected at the centre, normally achieved through stitched lacing. In the process of dyeing, the web threads are tied together. They contain identical patterns but in reverse order, so the join at the centre completes the two halves.

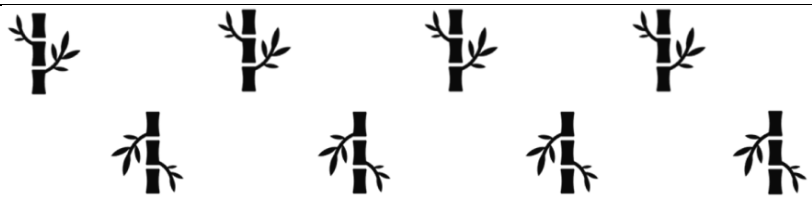
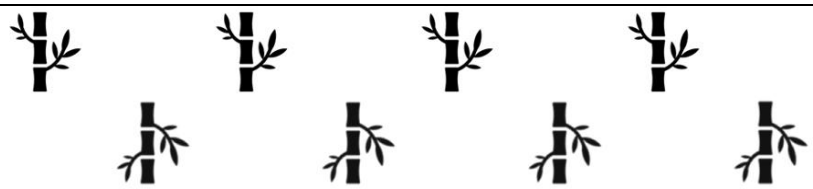
1.4. Frieze Pattern

Frieze patterns are concepts in mathematics used to categorise a design on a surface with two dimensions. The designs repeat in a single direction, according to the symmetrical content of the patterns. Studying these patterns mathematically indicates the occurrence of precisely seven pattern forms. They can be listed as translations, glide reflections, double parallel-vertical reflections, two half-turns, one reflection with a half-turn, horizontal reflections, and a triple reflection (one horizontal and two verticals) [7].

Mathematically, friezes or frieze patterns are surface designs in two dimensions which repeat in one direction. The repeating patterns may have rotational, reflection, or glide reflection and translational symmetry [8].The symmetrical arrangement of the frieze patterns is known as a frieze group. This refers directly to geometric transformation, the pattern's isometry set, the production of which requires the pattern to be retained through firm action and reflection[4]. Symmetry in a figure can be recognised as such only when any of the four isometries are included. There are three kinds of periodic patterns in a symmetry group, thebasis of which are either 2D or 3D planes. The former comprises frieze and wallpaper patterns, while the latter consists of crystal patterns**Error! Reference source not found.**. Studying frieze patterns mathematically indicates that, based on their symmetry, it is

possible to classify them into seven groups [11],[4]. People can find frieze patterns in many areas and cultures. These patterns are frequently used in architecture and decorative art.Common locations to find frieze patterns are the borders of wallpaper, decoration on built structures, workings on iron rails, and stitches in needlepoint; other uses are found[1]. In addition, frieze patterns are also applied in music.

Table 1. The frieze pattern recognition chart

Symbol of Frieze Pattern	Description	Frieze Patterns
11	One dimensional translation only, horizontal direction translation	
mg	Vertical reflection and 2-fold rotations, glide reflection	
1m	Horizontal Reflection	
12	A Half turn or 2-fold rotation	
mm	Vertical and Horizontal Reflection or 2-fold rotation	
1g	Glide Reflection	
m1	Vertical Reflection	

An individual weaver, particularly if they are from the senior generation, remain unaware that various concepts are being used by them when they work. These involve mathematics, properties of geometry, calculations, and measurements.

2.Literature Review

A detailed observation on previous studies is very important in order to get a general view of the floral fabric in the Iban community. There isonly a few research and studies about floral fabric that have been written in Sarawak. Therefore, the researcher will discuss the results from past studies, and relate them to the current study. This current study will cover some references from books, theses, and also articles from books and journals. One of the books is 'Tales and Legacy of An Iban Cultural Heritage in Sarawak: PUA'**Error! Reference source not found.**.

From the time of their first existence until today, Iban society has regarded *Pua* as being of great importance. This form of textiles is highly significant, as it is used every day and in ceremonies and rituals. In the traditional Iban stories, *Pua* is portrayed as God-given, so it is held in high regard for its distinct nature and sacredness. In Iban beliefs, their cosmic system explains all aspects of the world, including how gods have an impact on the life of mankind. Hence, this cosmic system has a strong influence over the way every significant activityis conducted. The making of the *Pu*a needs and demands discipline, meticulousness, effort, and determination to get the blessings of God, who is considered to be the *Petara*. The *Pua* represents the cosmology of the Sarawak Iban community, where the fabric is actually directly related to their customs and culture. Pua is considered a symbol of identity and icon of the Iban people, whether in relation to one Iban and another or between the Iban and their *petara* (god) or other supernatural powers.

Pua has a relationship with the supernatural or occult powers, and this is the main unique feature of the Iban Pua cultural heritage. The skill and expertise in *Pua*weaving is considered a symbol of high social status among women in the Iban society. Specific rituals were established relating to the status change of the Iban woman as measured by her skills and expertise with which they weave the *Pua.*The *Pua* is a special object that is bound to all aspects of life for the Iban people, and is an important element connecting the Iban people with the supernatural powers and the spirit world. Moreover, the *Pua* comes into being from an inspiration conceived in their mind, and is intended to capture something that is sacred and precious. Hence, the Iban will continue to uphold their tradition, and maintaining the local culture is a shared responsibility not to be neglected by anyone [14].

Pua Kumbu made by the Iban has qualities of uniqueness, since the creation of the designs stems from an extensive range of single motifs. The particular meanings of these are used together, producing tales of rituals and spiritual powers, as well as patterns. Every task in this process is undertaken by females, whose knowledge of the method of making *Pua Kumbu* is extensive [15].

In the work of a master weaver, a detailed pattern or design that emerges in the form of art on the yarn does not result from a definite personal artistic plan, which is first doodled and then woven. Every detail in the pattern originates from their dreams, during which their gods and the Divine Source whisper to them and show them the forms to create. Such a dream or vision, which has qualities of sacredness, can be experienced solely by someone who is specially selected. This person then has to realise the dream in practice, putting on the yarn a motif, a symbol, or a colour. All motifs depict, for those able to behold and interpret them, an interesting story whose message must be recognised [16].

An Iban Ritual book states that the floral fabric of *kumbu* has a relation to the ritual in the Iban community [17]. However, it focuses more on the motifs found on the floral fabric, the names of the motifs, and interpretation of those motifs. The book discusses the *Nakar* ritual, where, according to the book, it is usually performed at Entawau, Baleh, and Kapit. This ritual cannot be attended by men, and it should be performed in private. In addition, this book also discusses the relationship between dreams, war expeditions, and the process of weaving cotton.

Robyn Maxwell wrote a book called Textiles of Southeast Asia: Tradition, Trade and Transformation [18]. This book discusses the history, culture, and also the weaving techniquesin Asia, including countries such as India, China, Filipina, Thailand, Indonesia, and Malaysia. He also mentionedthe weaving in the Iban community, where coincidentally, the floral cloth of an Iban community from Sarawak was exhibited in Indonesia at that time. Moreover, he also explained that the weavers of the floral fabric are mostly Iban women, and they need to find comfort first for them to weave and to achieve dreams or spirit messages from the goddess as an essential preparation for weaving the floral fabric.

Susan, C. A. in her bookentitled The Sarawakian Series: Iban Culture wrote about how rituals were performed during an Iban wedding ceremony, and how the Iban also include the use of the *pua kumbu* in the ritual [19]. Furthermore, she also explained about mantras that are used during the ritual *bebiau* ceremony.

Robert Menua Saleh, in his book entitled Sampi Enggau Biau, clarified that according to the Iban people's beliefs, there are *petara-petara* (lesser gods) such as Kumang and Lulong that can transfer their expertise in weaving floral fabric *kumbu* to the Iban women [20]. According to Robert Menua Saleh, the *petara* Kumang and Lulong were believed to have exceptional skills and expertise in weaving floral fabric *kumbu*, and their skills and expertise can be

demoted to a few Iban women that are lucky to get them through dreams and gifts from *pengaroh*.

2.1. Symmetry and Transformation Concept in Pua Kumbu

Most of *Pua Kumbu's* designs are influenced by the concept of symmetry. Defining the concept of symmetry refers to a precise correlation, in terms of shape and size, of the design's two halves. Symmetry also refers to the pattern of roughly identical components facing each other or around an axis [21]. It is possible to obtain symmetry and experts agreed it is through translation, rotation, reflection, or glide reflection, each of which is a perspective [21]. Other findings suggested that a variation of these basic operations is also a perspective in symmetry concept [10].

If all the motifs and patterns are to be successfully classified according to their groups of mathematically-based patterns, each symmetrical perspective of the patterns in *Pua Kumbu* must be examined [1]. According to research by Nawawi, the following are the perspectives of symmetry concepts used in *Pua Kumbu's* design motifs [21].

Translation involves motifs or patterns moving repetitively upwards or downwards, to the left or right, or in diagonal directions. During these movements, they remain orientated in the same way. In terms of distance and direction, the way all the points of the pre-image move is the same as the image thus the points create the translation, as formally described.

Rotation involves a point around which motifs or patterns repeat. This creates transformations due to the way objects 'spin' round an unmoving location, the rotation centre. The angle at which an object rotates is 60°, 90°, 120°, or 180°and can take place in a direction that is clockwise or counter-clockwise.

Reflection involves an object being 'flipped' over a reflection's axis. Another way of describing this is a motif's reflection, in which the inversion of an image occurs, as it would with a mirror.

Glide reflections can be identified by motifs translating along the axis and being simultaneously reflected across an axis.

2.2. Pua Kumbu Patterns

The basic structure of *Pua Kumbu* (Fig. 1) consists of:

- *Buah pua*, the main part of the cloth
- *Kelemebai* or *sengkalan*, the fencing of the cloth
- *Punggang pun*, the preceding accompaniment
- *Punggang ujong*, the proceeding accompaniment
- *Anak pua*, the side borders of the cloth
- *Ara* and *tisi*, the selvedge of the cloth.

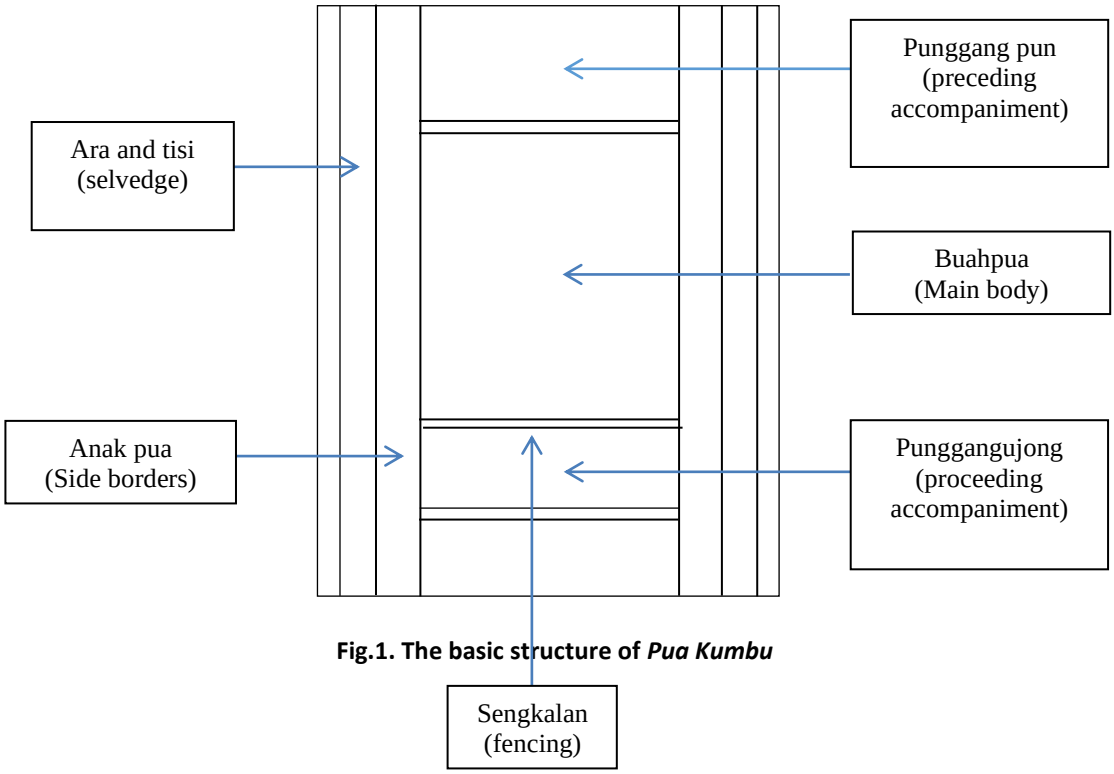


Fig.1. The basic structure of *Pua Kumbu*

Weavers follow a rapidly-changing traditional practice. Therefore, a point of constancy is required to identify the borders and characteristics in order to be respectful towards a century-old tradition.Hence, there are six key elements to *Pua Kumbu*: *buah pua* (central body), *kelemebai* and/or *sengkalan* (fence), *punggang pun* (the accompaniment that goes before), *punggang ujong* (the accompaniment that goes afterwards), *anak pua* (borders at the side), and *ara* and *tisi* (selvedge). The *Pua Kumbu* cloth demonstrates a weaver's grasp of Iban culture harnessed in the form of motifs and patterns [23]. These cultural yarns contribute to the telling of a personalised message. In *Pua Kumbu*, repeated patterns and motifs are ubiquitously displayed, similar to many artistic designs.

3.Result and Discussion

The current study analyses the principles of symmetry in the designs of *Pua Kumbu*, investigating how the motifs forming the frieze pattern are arranged.The frieze pattern has seven different types, and from the selection of the *Pua Kumbu* designs, the patterns of *Pua Kumbu* can be classified using the frieze pattern recognition chart in Table 1 above. From our findings, we realised that all *Pua Kumbu* patterns bear at least one of the seven frieze pattern design. Seven kinds of frieze patterns have been identified, comprising of type 11, mg, 1m, 12, mm, 1g, and m1. From the frieze pattern recognition chart in Fig. 1, we can classify the *Buah Pua* pattern on the *Pua Kumbu* of Fig. 2 as a frieze pattern type mm.The pattern of *Pua Kumbu* contains vertical reflection and horizontal reflection. In Fig. 3, the frieze pattern is also taken from the *Punggang Ujong* part of the *Pua Kumbu*. There is vertical reflection, but it has no horizontal and glide reflection.Hence, this frieze pattern is classified as type m1. In Fig. 4, the frieze pattern is taken from the *Buah Pua* of the *Pua Kumbu*.Since there is horizontal reflection but no vertical and glide reflection, this frieze pattern is classified as type 1m by referring to the Frieze Pattern Recognition Chart. On the other hand, the*Buah Pua* of the *Pua Kumbu* pattern in Fig. 5 is classified as type 1g, which is glide reflection. From Fig. 6, the frieze pattern shown in the *Pua Kumbu* is taken from the *Punggang Ujong*section. The frieze patterns have vertical and horizontal reflection or 2-fold rotation.Thus, according to the Frieze Pattern Recognition Chart, the pattern can be classified as type mm. It was not able to determine mg and 12 patterns. Themg pattern consists of vertical reflection, glide reflection, and 2-fold rotations. The type 12 pattern consist of a half-turn or 2-fold rotation. Throughout this research, we noticed there were not many transformations of the form type 1m, 1g, and 12 patterns.All three patterns do not have vertical reflection.This pattern is a bit tricky to discover since almost all *Pua Kumbu* have vertical reflection. The results show that type m1 is widely used followed by type mm. The type m1 is the most easy and simplestpattern to weave.The type mm is more complicated than the other types, but it is widely used in *Pua Kumbu* designs despite its complexity.Prior to the woven process, the threads are continuously pulled from one end to the other end of the weaving equipment called *tangga ubong* until it becomes a web as shown in Fig. 7.From here, the warp technique is applied by tying a part of the web to get the desired pattern. As Fig. 8 illustrates, a pattern is created through the exclusion of dye from elements of the tying web.

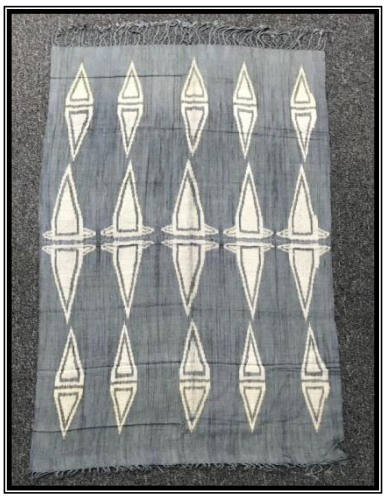


Fig. 2. *Buah Pua* pattern

Fig. 3. *Punggang Ujong* pattern

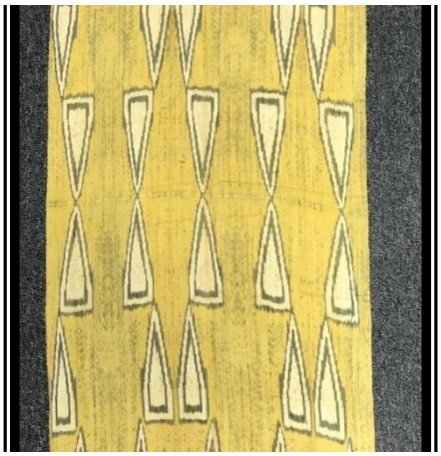


Fig. 4. *Buah Pua* pattern

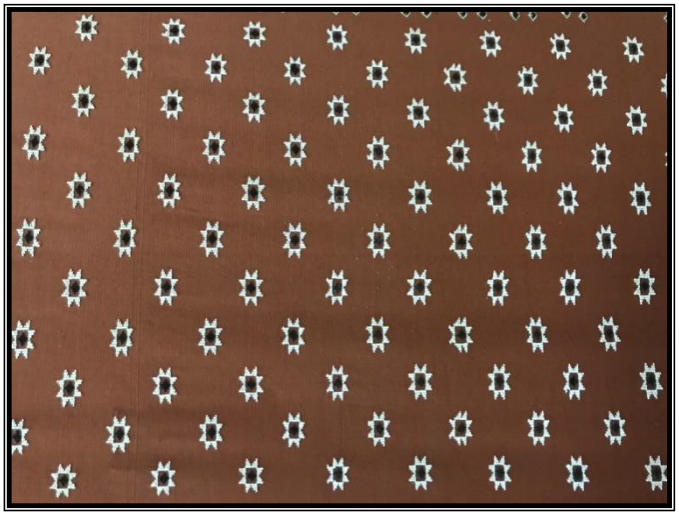


Fig. 5. *Buah Pua* pattern

Fig. 6.*Punggang Ujong* pattern

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Fig. 7. Preparation of yarn before weaving: *Nabu* (thread is wound into a ball); *Ngirit* (a thread skin is horizontally stretched and pulled), *Ngarap* (the alternative warp is selected); and *Negi*, *Nipan,* and *Ngebat* (threadis tied).

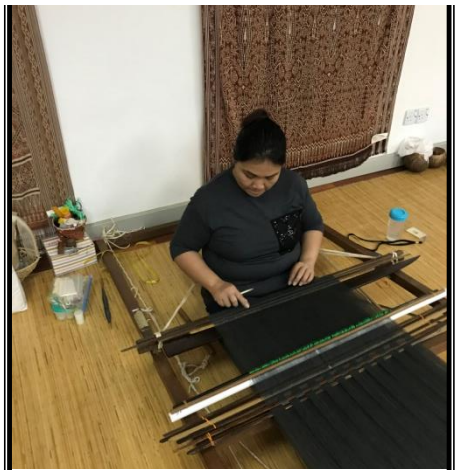

Fig. 8.The weaver weaving on the *tangga ubong*

Fig. 9. Vertical reflection patterns of *Pua Kumbu*

The vast majority of the designs of *Pua Kumbu* contain patterns that are reflected vertically.As illustrated in Fig. 9, the webs above and below are taken from cloth pieces that are identical and connected along the selvedge using stitched

lacing.*Buah pua* is the main pattern or main body of *Pua Kumbu*. The main body of the cloth is woven on a backstrap loom, and both ends of the textile are typically finished with a crowfeet pattern. The upper and bottom webs are similar pieces of fabric linked together with a lacing stitch along a selvedge to make a huge blanket-sized textile known as *Pua* (Fig. 10). To impart solidity and good weaving quality to the edges of the *Pua*, one or two rows of coarse twining are usually used.

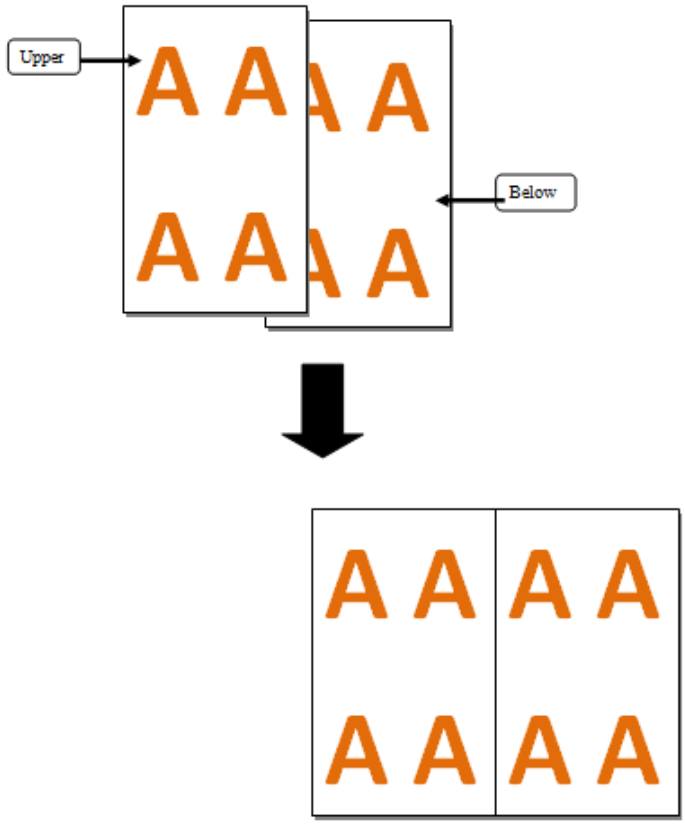

Fig. 10. The illustration of the upper and bottom fabrics after linked together

The problem in finding the mg pattern arosesince almost all of the*Pua Kumbu* patterns do not consists of glide reflection. Glide reflectionis defined as a pattern sliding to the right, which is then reflected in the line (Fig. 11).

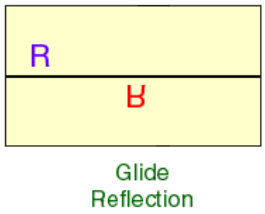

Fig. 11. The glide reflection process

In simple words, the pattern must translate to the right (Fig. 12);

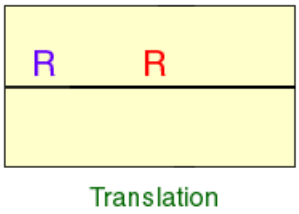

Fig. 12. The translation process

then reflect horizontally (Fig. 13).

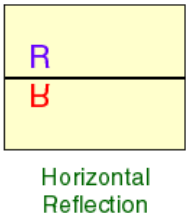

Fig. 13.The horizontal reflection process

There is only one pattern that we could not find which is type 12 of the frieze pattern. This pattern is impossible to find as the pattern consists of only 180° rotation (Fig. 14).

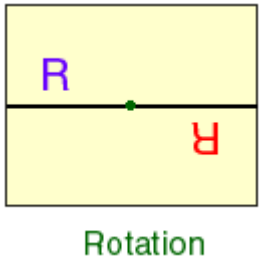

Fig. 14. The rotation process

Compared to 1g patterns that have to be translated then reflected horizontally to get the glide reflection, thetype 12 pattern only has rotation (Fig. 15).

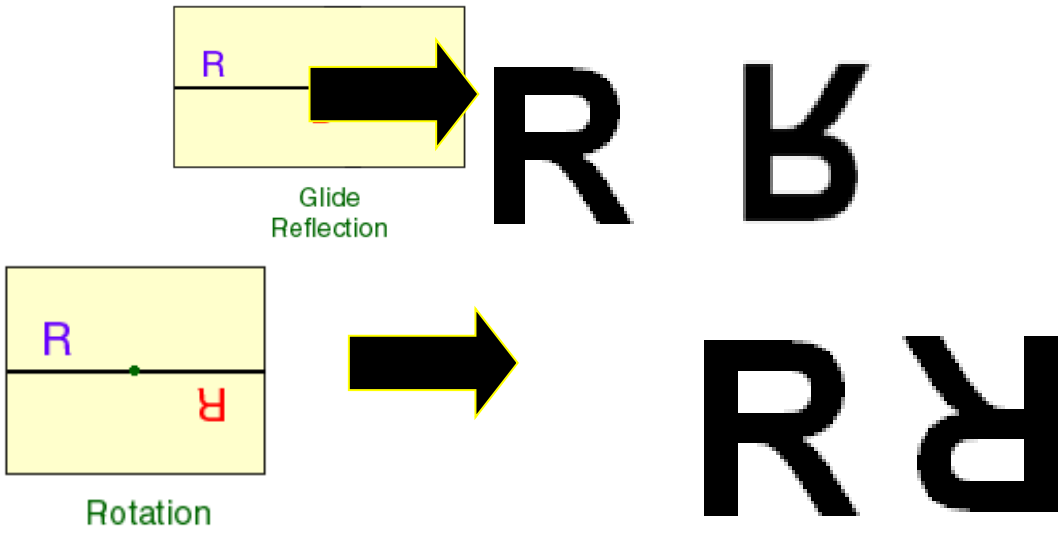

Fig. 15. The translation process of type 1g (glide relection) and type 12 (two half turns)

From these findings, we noticed that almost all *Pua Kumbu* designs have vertical reflection or horizontal reflection.Nature is actually very geometric, and the weavers have been and are inspired by nature.Fig. 16 shows examples of this in depictions of ferns and bamboo shoots.The *Pua Kumbu* pattern in Fig. 17 was designed using a combination of ferns and bamboo shoots motifs.

Fig. 16. Phyllomorphic designs such as ferns and bamboo shoots are often represented in *Pua Kumbu* designs.

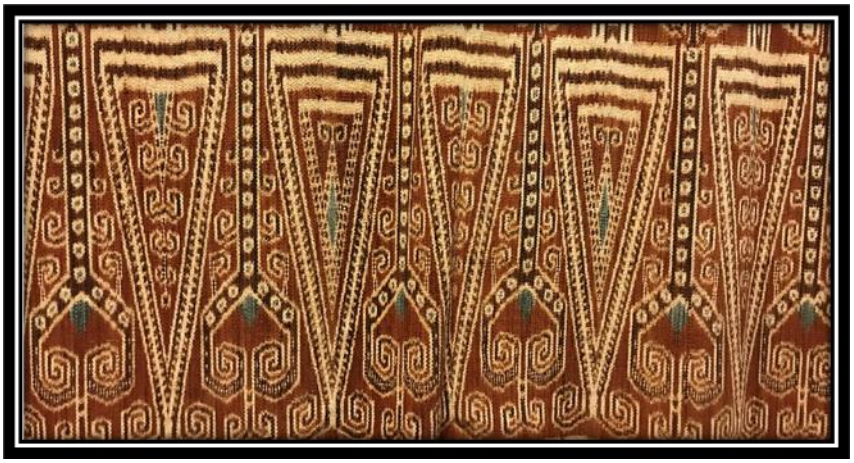

Fig. 17. Symmetry in *Pua Kumbu* pattern with ferns and bamboo shoots motifs.

Besides being inspired by nature, the weavers are also inspired through dreams.This particular dream is only given by the weaving goddess *Kumang*, where the goddess will show the designs of *Pua Kumbu* for the weaver to weave.Only chosen and powerful weavers are allowed to weave powerful motifs such as mystical creatures.

4.Conclusion and Recommendation

This research intends to identify the mathematical concepts and mathematical patterns in the *Pua Kumbu* patterns using frieze group. While *Pua Kumbu* refers to a form of textiles, indigenous to Sarawak and may, on occasion, be termed a blanket, however it is more appropriate to call it a cloth.The analysis of the results showed that the Pua Kumbu designs are rich with mathematical shapes, patterns, and concepts. Our research shows that mathematical concepts actually exist in the designs of *Pua Kumbu,* even though the Iban weavers are not mathematicians and do not have any knowledge of mathematical patterns and concepts. Therefore, people can measure the value of *Pua Kumbu* not only by its exotic values, but also by the mathematical concepts that exist in the *Pua Kumbu* patterns.

The mathematical concepts that exist in the *Pua Kumbu* can be identified using the Frieze Pattern Recognition Chart.The *Pua Kumbu* patterns identified were classified into seven frieze patterns, namely type 11, mg, 1m, 12, mm, 1g, and m1. Each *Pua Kumbu* design has its own type of pattern depending on the motifs of the pattern of *Pua Kumbu*. Natural living features such as animals and plants comprise the majority of the motifs.Although there has been social progress in the Iban community, and former belief systems and customs have been largely supplanted by innovative ideas, *Pua Kumbu* remains valuable in terms of the fundamental ritualistic and practical procedures governing the weaving process.

The concepts used in the study underlie the subject, design, and aesthetic meaning to classify the pattern of paintings of *Pua Kumbu* by using a symmetrical transformation process. Implications from the study showed that paintings that are looked at from the view of art appreciation can also be seen through the repetitive geometric system and reflection of images forming interesting combinations of composition, therefore, it is not only seen from the formalist point of view of art alone. The benefits of this paper include acting as a valuable guide for related professions and as future reference on the uniqueness of producing *Pua Kumbu* patterns and their designs. The

production of *Pua Kumbu* design has its own story. It also serves as evidence of the existence of geometric and symmetrical patterns in the creation of *Pua Kumbu*, which is a valuable contribution to the traditional design of the Iban people. The textile industry in Sarawak can eventually become an example for other Malaysian arts or crafts to create ideas and techniques effectively. Moreover, this study will be a route for mathematical researchers to build a suitable mathematical model to produce unique *Pua Kumbu* patterns digitally.

The study focuses on the mathematical analysis of patterns in *Pua Kumbu*, which can be categorised according to transformation and symmetry principles.According to the research, it is possible to use the frieze pattern's transformational geometrical character to analyse the designs in the patterns of *Pua Kumbu*. Most of the motifs on these parts of the *Pua Kumbu*are type mm, m1, 1m, 1g, and 11of the frieze pattern. Furthermore, there are still more patterns in *Pua Kumbu*that need to be investigated, thus this research should continue. For future research on these frieze patterns, we recommend that the next researchers conduct research on the frieze patterns of traditional and modern patterns of *Pua Kumbu*, where they can determine whether this frieze pattern exists in traditional or modern or both. Besides, we hope that the *Pua Kumbu*patterns are maintained so that the traditional value of this exotic pattern will be preserved. We also recommend future researchers to do research on *Pua Kumbu* using the GeoGebra method as it is more accurate and reliable.It will also reduce the errors when the pattern of the *Pua Kumbu* is traced.

Acknowledgment

The authors appreciate the thoughtful comments of the anonymous reviewers and the handling associate editor. Not to mention, the authors want to express their gratitude to all of the participants for their generous involvement in the study, as well as positive cooperation and feedback. The researchers would like to express their gratitude to the Centre of Research and Innovation Management (RIEC), Universiti Malaysia Sarawak, Malaysia for their assistance in providing CDRG financial support for this project.

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