# Frieze Pattern Analysis of the Eastern Cordillera three Major Ethnic Groups Woven Native Attire

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**Abstract**

Mathematics is everywhere. Its beauty is seen in man's awareness of the environment. Aiming to penetrate a society's cultural component, ethnomathematics targeted indigenous weaving patterns. Ifugao (Tuwali, Kalanguya, and Ayangan) and Ga'dang (Ga'dang and Balangao) have their own individual weaving patterns which were culturally included, therefore earning their merit to be studied. Aims of knowledge collection included preserving the Eastern Cordillera's distinctive character and appreciation of mathematics and culture. The research employed a method of assessing frieze patterns in local woven attires. The Eastern Cordillera weavers employed the seven frieze group designs in their traditional clothing. The asymmetry of traditional clothing is studied using group theory and transformation geometry. The utilization of motifs that represent cultural ideas and traditions, as well as weaving style and process, favors distinct frieze and plane crystallographic groupings. The study's findings indicate the weaver's ability to create key geometric shapes without rigorous mathematical knowledge. This study directly contributes to the field of mathematical crystallography in art and cultural heritage, which uses group-theoretic approaches and tools to comprehend the mathematics in artworks from all over the globe. It adds to the expanding corpus of literature that employs symmetry to increase cultural understanding.

**Keywords**: Frieze Pattern, Culture, Woven Native Attires, and Symmetry

## I. Rationale

Mathematics is classified both as an art and as a science. It is hardly running out with difficult problems, calculating numbers, memorizing formulas or proving theorems, but it also includes skills, such as picking out patterns, storing data and making objects. Though mathematics is regarded as one of the most difficult fields to learn, man unconsciously have been using it in any activity. It is just that only a few recognize and appreciate its abstract existence while others create a notion that it is more of a problem than a fun. But like other fields of study, the essence of mathematics is the way it enables us to express, communicate and reason about ideas and especially ideas about our world. Thus, the importance of mathematics lies in its application to our daily lifestyle.

One of the objectives of mathematics, nowadays, is to show or bring an appreciation of its connection to another field of interest like ethnomathematics, the most applied studies of mathematics.

Weaving, one of the culturally rooted works of the society is a highly mathematical task. Men and women who weave understood its mathematical dimension even without executing the formal mathematics. The Ifugao, Ga'dang, and Balangao are the tribe, it branches out of the three different main tribes in the eastern part of Cordillera, which differ in dialects, traditions and customs, and with the design of their clothing. The weavers were able to memorize the sequence of the repeating patterns and these were highly preserved by the Cordilleran weavers, but the uniqueness of every costume seems to fade or unrecognized as modernization and changes of social lifestyle are embraced by the youth.

## II. Review of Literature

### Ethnomathematics

Csapo (2007) stated that Culture is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society.

TD'Ambrosio (1985) used the term ethnomathematics to describe the mathematical practices of recognized ethnic groups, and it may be considered the study of mathematical ideas found in any culture. According to D'Ambrosio (2001), ethnomathematics is the study of how people from diverse cultural groups develop techniques for describing and comprehending their environment in response to difficulties, struggles, and human survival attempts. He defines ethnomathematics as follows: "Today, the prefix ethno is accepted as a very broad term that refers to the social cultural milieu, which includes language, jargon, behavioral norms, myths, and symbols. The term mathema has a complicated history, but it often refers to "explain," "know," "comprehend," and "perform" operations such as ciphering, measuring, classifying, inferring, and modeling. The suffix tics is derived from the same root as technique. In other words, ethno refers to members of a group who are identifiable by their cultural traditions, codes, symbols, myths, and distinctive modes of reasoning and inference within a cultural environment (Rosa & Orey, 2007). Tics are methods such as counting, ordering, sorting, measuring, weighing, ciphering, categorizing, inferring, and modeling, while mathema is a way of explaining and comprehending the world in order to transcend, manage, and deal with reality in order for individuals and cultural groups to live and flourish. According to Rosa and Orey (2003), the mathema generates the tics within the ethnos framework because it encompasses daily problems that people face, larger global challenges, and human attempts to construct a meaningful society.

Rosa and Orey (2011) said that ethnomathematics has shown that mathematics is comprised of many different and distinct cultural traditions and that it puts a premium on indigenous mathematical concepts, procedures, and practices. Additionally, they said that humans have evolved logical processes in response to the universal need to define, categorize, measure, explain, understand, and model many elements of our world. All of these traits have shaped and functioned differently in various social, cultural, and historical settings. Thus, each culture group develops its own method of mathematics, the links between which reflect specific cultural value systems, most notably in the manner in which they quantify and utilize numbers, geometric shapes and relationships, and measure or categorize things in their own environment.

For these reasons, many cultural groups have created their own system for mathematically representing their reality (Bassanezi, 2002; Rosa & Orey, 2015). Furthermore, According to D'Ambrosio (1993), the ethnomathematics program's mission is to recognize the diversity of mathematical practices by examining the appropriation of academic mathematical knowledge developed by various sectors of society, as well as the diverse ways in which different cultures negotiate their mathematical practices. The aim of ethnomathematics is to contribute to both cultural and mathematical knowledge, and to foster an awareness for the links between the two (Wikipedia, n.d.). According to Barton (1996), ethnomathematics is a field of study that examines the manner in which various cultural groups understand, express, and apply ideas and activities classified as mathematical practices.

Borba (1997) defined ethnomathematics as the process through which members of a given culture use mathematical concepts and ideas to address quantitative, relational, and spatial elements of their life.

Rosa and Orey (2003) assert that kids develop an understanding of mathematics when they become aware of mathematics in their culture.

According to Orey (2004), although ethnomathematics has only recently received attention from mathematics educators, anthropologist often comment on the peculiar uses of the mathematics among indigenous group. Just like the other branches of ethnoscience such as ethnobiology, ethnochemistry, and ethoastronomy that have gained acceptance around the turn of the century and have a history as recognized disciplines, the formal development of ethnomathematics may have been shown that mathematics is universal and culture free. However, recent researches are revealing that much of the mathematics use daily practice, as affected by distinctive modes of cognition, may be quite different from that which is taught in school.

**Frieze Pattern**

Pattern is defined by the Oxford Dictionary (1996) as a repeating ornamental design on wall paper, fabric, and the like. They are ubiquitous: window pales, roof tiles, wooden slats in a fence, bricks in a wall, railway sleepers, heaps of logs, trees in a forest, wallpaper, and textiles, to name a few. Nor are they restricted to man-made objects, as the beautiful hexagonal pattern of snow crystals under a microscope demonstrates; the honeycomb, the flower-head, pineapples, and fir cones, as well as the simple crystals of common salt. Indeed, patterns owe their regularity and beauty on an underlying mathematical structure that even the most meticulous designer may be unaware of entirely. However, people who want to analyze and comprehend patterns, such as crystallographers and researchers who infer the structures of molecules from X-ray diffraction patterns, must be familiar with this structure.

A pattern is the result of a recurring topic in a methodical way (Budd, 1972). The basic pattern-unit, or "motif," or germ-idea, may be coupled with certain geometric transformations that preserve distance (rotations, translations, reflections, and glide reflections), resulting in a symmetric aggregate of the figures generated.

Analysis of symmetries, according to Berczi (1989), may be extremely useful in better understanding ancient art and artifacts. He went on to say that the various kinds of symmetries may assist trace connections between different cultures in addition to being an obvious mathematical evolution of beautiful art.

Frieze Pattern is described by Mc Escher (2016) as an endless strip with a repeating pattern, or occasionally a border pattern or an infinite strip pattern. A frieze is a decorative carving or pattern that runs horizontally immediately below a roofline or ceiling in architecture.

Morier-Genoud et al. (2012) described frieze as a pattern that repeats in one direction and is often used as architectural decoration. A mathematical study of symmetries shows that for a discrete one produced by translation, reflection, and a half rotation, there are seven distinct frieze patterns conceivable. The seven distinct groups are designated using Hermann-Mmauguin notation and correspond to a seven-infinite sequence of axial point groups in three dimensions. Orbifold notation, Coxeter notation, and Schonflies notation are all examples of notation. Furthermore, frieze groups are linked to wallpaper groups and are continuous subgroups of the Euclidian plane isometries. However, frieze groups are more limited than wallpaper groups since the former has only one translation. In a frieze group, reflection angles may only be parallel to the translation on the pattern's centerline or perpendicular to the translation. Another restriction is that only rotations of order two are permitted. As a result of these constraints, the patterns of frieze groups are strips. That is why they are referred to as strip patterns by some.

McDonald and Weston (2004) define frieze patterns as border patterns that are frequently seen in wallpaper borders, decorations on ceramics, ornamental designs on buildings, needlepoint stitches, ironwork railings, and many other locations. Its distinguishing features include symmetry and repetition, which set it apart from other border designs. They also categorized the frieze patterns statistically based on the types of symmetries they had, giving birth to just seven symmetry classes as represented in the arts and crafts of North America's indigenous peoples.

**Weaving**

Weaving is a method of textile production in which two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth. In general, weaving involves using a loom to interlace two sets of threads at right angles to each other: the warp which runs longitudinally and the weft (older woof) that crosses it. One warp thread is called an end and one weft thread is called a pick. The warp threads are held taut and in parallel to each other, typically in a loom (Wikipedia, nd.).

Temesgen (2019) stated that weaving is the most popular way of fabric manufacturing. It is primarily done by interlacing two orthogonal sets (warp and weft) of yarns in a regular and recurring pattern. Moreover, he added that actual weaving process is preceded by yarn preparation processes namely winding, warping, sizing, drawing and denting textile fabrics are generally two-dimensional flexible materials made by interlacing of yarns or inter-meshing of loops with the exception of nonwovens and braids.

Lamb and Johnson (2004) considered weaving as an ancient textile art and craft that involves placing threads or yarn made of fiber onto a warp and weft of a loom and turning them into cloth. They also added that in the past, simple fabrics were woven on dobby looms and the jacquard looms were reserved for more complex patterns but as computer controlled jacquard looms have become more popular, it is more economical for mills to weave all their fabrics on jacquard looms so that one set-up may be used for all designs. Weavers nowadays employ threads spun from natural fibers such as cotton, silk, and wool, as well as synthetic fibers like as nylon and orlon, in contrast to ancient times when they used natural grasses, leafstalks, palm leaves, and thin strips of wood. Today, weaving is a significant industry in a number of nations. Oftentimes, weaving is done on high-speed looms. Boot weaving is used to produce not only fabric and textile goods, but also screens, metal fences, and rubber tire wire. According to Flores (2000), almost all over the world, people employ mundane task of weaving: be it cotton, carpet or silk. However, weaving is a highly mathematical task and men and women who weave understand its mathematical dimension without doing the formal mathematics.

**Synthesis**

The ethnomathematical analysis on the woven fabrics of the Eastern Cordillera can give clear understanding on the relationship between mathematics and native attires. This can be an estimate on the depth geometric imagination and inventiveness reflected by the Eastern Cordillera weavers.

III. Objectives

This study was descriptive in nature which focused on the analysis of the frieze patterns created on the three major three major ethnic groups' woven native attires.

Specifically, it sought to:

1. Determine the different frieze patterns created in the weaving of native attire;
2. Identify the common motifs on the weaving of native attire by using mathematical methods of frieze pattern; and
3. Compare and contrast the frieze patterns created in the weaving of native attire by each group (Ifugao, Ga'dang, and Balangao).

## IV. Procedure/Methodology

This study is geometrical exploration in nature in the context of culture. Thus, a descriptive process will be used.

The study will be conducted at the Eastern part of Cordillera particularly from the municipality of Alfonso Lista, Ifugao and Paracelis, Mt. Province.

The respondents are the ethnic groups (Ifugao, Ga'dang, and Balangao) residing at the eastern part of cordillera particularly the municipality of Alfonso Lista, Ifugao and Paracelis, Mt. Province.

The unstructured questionnaire will be used to gather the needed data or information from the respondents.

The researcher will gather all designs of native woven attire from the three ethnic groups (Ifugao, Ga'dang, and Balangao) of the eastern part of cordillera particularly the municipality of Alfonso Lista, Ifugao and Paracelis, Mt. Province. In every ethnic groups will be identified and group as one in order to have an easier analysis for contrast and comparison. Interview will be done specially to elders for the explanations on the distinct of designs.

For the frieze pattern analysis, the method of analysis will be adopted from study of Chidtavong, et al. (2016) entitled "Digitizing Traditional Lao Textile to Modern Weave Technique" with some changes for easier analysis.

## V. Discussion of Results

This chapter presents the treatment of all gathered attires through frieze pattern analysis. All attires gathered were exclusively from each of the three ethnic groups in Ifugao, Ga'dang and Balangao taken from any place where the cloth is available.

### IFUGAO

### *A.* Ayangan Attires

### 1. G-String (Lenchom) for Men

Figure A.1.1: "Pfinohlan"

Figure A.1.1 shows one of the men's lower cloths which is considered as the simplest attire among the 'lenchom' having two horizontal red design. It is dominated by black background and added with stripes of red and yellow together with frieze pattern of white color. This attire can be used as death attire.

Figure A.1.2: “Phinodfod”

Figure A.1.2 shows a cloth which is purposely death attire for dead men but can be used as a dowry of man to the 1st pregnancy of a woman (wife). It made use of frieze pattern using men design at the center of the cloth. The cloth has a dark blue background with stripes of red, yellow, and white color added in it. Frieze pattern of letter “W” design were also formed at the horizontal design found at the edge of the attire.

Figure A.1.3: “Kargacha”

Figure A.1.3 shows the daily wear attire and could be used in any occasion. It has three horizontal designs with frieze patterns in each using parallelogram design. It made use of blue, red, yellow, and white stripes with frieze pattern of men design at the light blue stripes.

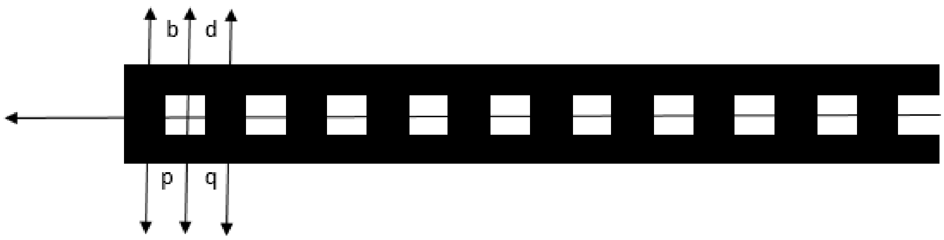



Figure A.1.1.1: Frieze Group Pattern Formed by Box Design in the “Phinohlan” and “Pfinodfod” Attire

Figure A.1.1.1 shows the pattern found at the near middle strip of the cloth. It is formed by white boxes embedded in a black background.

Figure A.1.1.1.1: Motif b of the Frieze Pattern formed by the Box Design

Figure A.1.1.1.1 shows the motif b that is being used to form the entire pattern. Motif b was reflected over a vertical line producing and also horizontal line to form d and p respectively. Then the motif b made a 2-fold rotation or half turn to produce q. Through translation, the whole pattern was being formed. Thus, the frieze pattern is p2mm (reflection over a vertical line and horizontal line and translation).

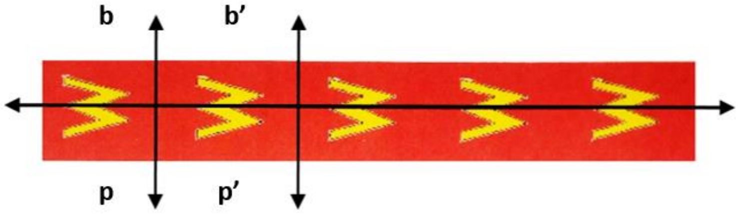



Figure A.1.2.1: Frieze Group Pattern Formed by Letter “W” in the “Pfinodfod’ Attire

Figure A.1.2.1 shows a frieze group pattern formed by the letter “W” design found at the edge of the attire embedded in a horizontal design. It made use of red background and the letter “W” was colored with yellow.

Figure A.1.2.1.1: Motif b of the Design Formed by Letter “W” Design

Figure A.1.2.1.1 shows the motif of the pattern formed by letter “W” design. The motif b made a horizontal reflection forming the p. The b’ and p’ were formed through translation from b and p. Then, the other figures were formed through simultaneous translation. Therefore, the frieze pattern is p11m (reflection over a horizontal line and translation).

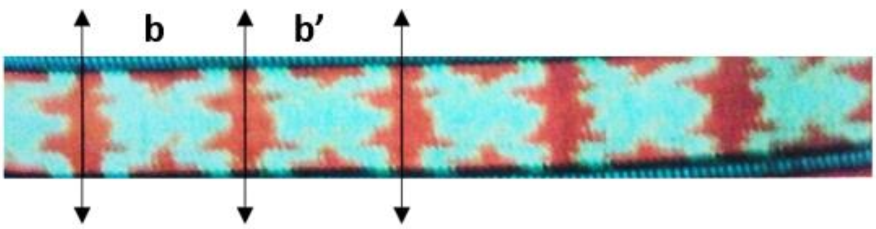



Figure A.1.2.2: Frieze Group Pattern Formed by Men Design in the “Pfinodfod” Attire

Figure A.1.2.2 shows the frieze group pattern formed out of men design which was found at the middle stripes of the cloth. The irregular shapes of men were colored white with red background.

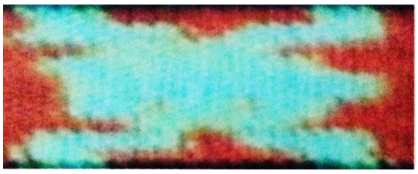


Figure A.1.2.2.1: Motif b of the Design Formed by Men Design

Figure A.1.2.2.1 shows the motif of the pattern formed by men design. Motif b made use of translation only in order to form b' and continues the translation until the whole pattern is made. Thus, the frieze pattern is p1 (translation only).

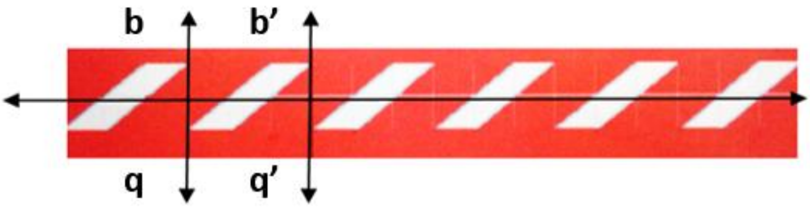



Figure A.1.3.1: Frieze Group Pattern Formed by Parallelogram design in the "Kargacha" Attire

Figure A.1.3.1 shows the frieze group pattern formed by parallelogram design found at the three-horizontal design of the cloth. The white parallelograms were embedded on a red background.

Figure A.1.3.1.1: Motif b of the Design Formed by the Parallelogram Design

Figure A.1.3.1.1 shows the motif of the pattern formed by parallelogram design. Motif b made a half turn (rotation) to produce q. Then, the design formed by band q was repeated through translation to produce the whole pattern. Thus, the frieze pattern is p2 (rotation and translation only).

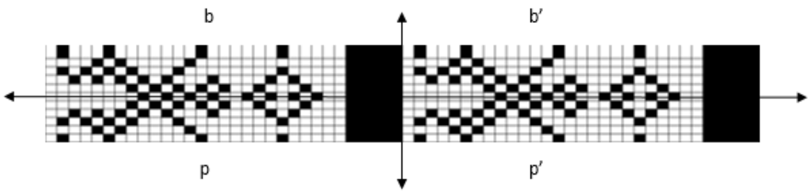



Figure A.1.3.2: Frieze Group Pattern Formed by the Men Design in the "Kargacha" Attire

Figure A.1.3.2 shows the frieze group pattern formed by the men design found at both side of the cloth. Since the cloth made use of blue as the dominant color instead of black, the blue design is heavier in color than the background.

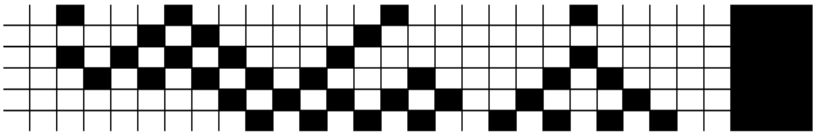


Figure A. 1.3. 2.1: Motif b of the Design Formed by Men Design

Figure A.1.3.2.1 shows the motif of the pattern that made use of men design. The motif b had a horizontal reflection to produced p forming the complete image of a man. Then, b and p use translation to produce b' and p'. The process continued until the whole pattern was formed. Therefore, the frieze pattern is p11m (horizontal reflection and translation).

**2. Skirt (Lammuy) for Women**

Figure A.2.1: "Pfinnalit"

Figure A.2.1 shows the "Pfinnalit" attire which is the most commonly used attire as skirt for women. The cloth consists of white, blue, and red stripes with the green frieze pattern made up of arrows embedded in the red stripes.

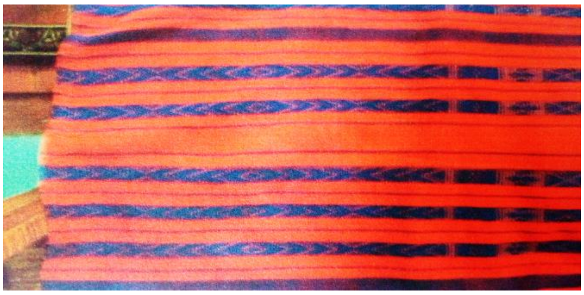


Figure A.2.2: "Pfayya-ung"

The figure A.2.2 shows the attire that was copied from the "Tuwali" group in Banaue. It was adopted due to the closeness of Banaue and Mayoyao. The cloth made use of red and blue stripes with frieze pattern of white arrows embedded in the blue stripes.

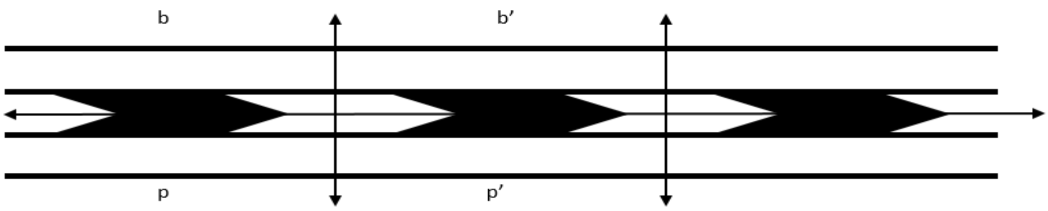



Figure A.2.1.1: Frieze Group Pattern Formed by Arrow Design in the “Pfinnalit” Attire

Figure A.2.1.1 shows the frieze group pattern formed by arrow design found in the near middle stripes of the cloth. The design made use of green arrows embedded in a red background.

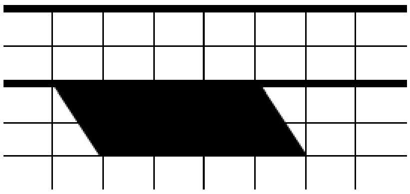


Figure A.2.1.1.1: Motif b of the Design Formed by Arrow Design

Figure A.2.1.1.1 shows the motif of the design of the pattern formed by arrow design. The motif b uses horizontal reflection to produce p and to create the image of an arrow. Translation was also used to produce the pattern on the cloth. Therefore, the frieze pattern is p11m (horizontal reflection and translation).

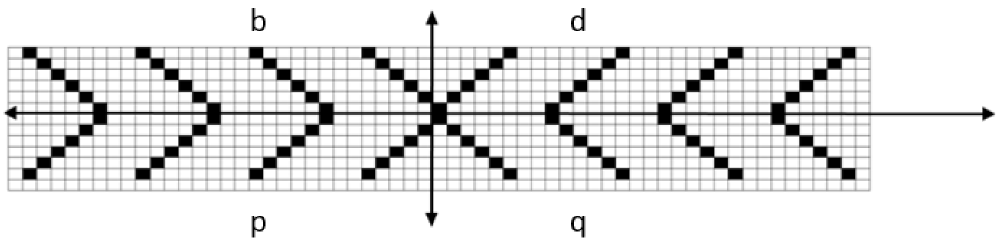



Figure A.2.2.1: Frieze Group Design Formed by Arrow Design in the “Pfayya-ung” Attire

Figure A.2.2.1 shows the frieze group pattern formed by white arrow design which is found at the blue stripes of the cloth. The pattern made use of four arrows facing another four arrows.

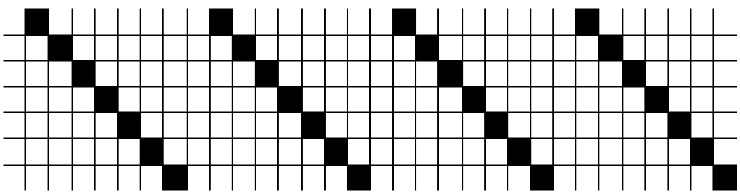


Figure A.2.2.1.1 Motif b of the Design Formed by the Arrow Design

Figure A.2.2.1.1 shows the motif of the pattern formed by the arrow design. Basing from the motif b, the design made use horizontal reflection and vertical reflection in order to create the complete image. Then, translation happened to form the pattern. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

### 3. Belt (Al-lot) for Women

Figure A.3.1: “Chukaw”

Figure A.3.1 shows one of the women’s belt known as “Chukaw” which is usually paired with “Pfinnalit” attire. The two stylistic design of the cloth could be placed at both end of the white elongated cloth or at the near middle of the cloth depending on the weavers’ style. The two colorful designs made used of green, red, yellow, blue, and white color combined.

Figure A.3.2: “Majad”

Figure A.3.2 shows another belt known as “Majad” which is usually paired with the “Pfay-yaung” attire. This is the most common attire usually used in every occasion in Ifugao. The attire made used of black arrow and triangle design and yellow and red background combined to form a pattern.

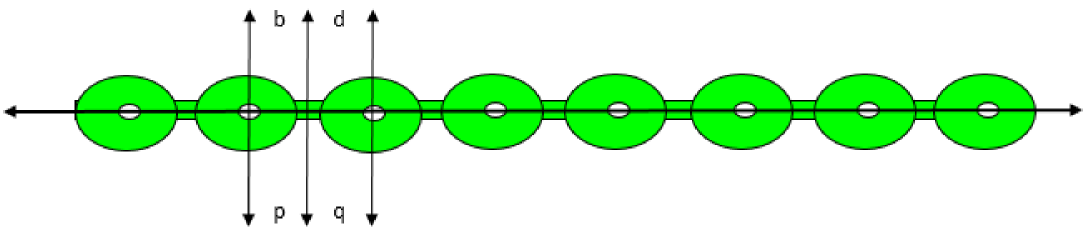



Figure A.3.1.1: Frieze Group Pattern Formed by Circle Design in the “Chukaw” Attire

Figure A.3.1.1 shows the frieze group pattern formed by connected circle design found at the colorful part of the cloth. The design made use of green doughnut shape connected with each other and embedded in a white and yellow background.

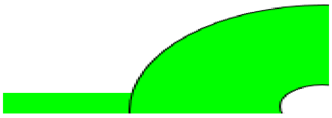


Figure A.3.1.1.1: Motif b of the Design Formed by Circle Design

Figure A.3.1.1.1 shows the motif of the pattern formed by the circle design. Basing from the motif b, the design made use of horizontal and vertical reflection to produced p and d. Then, the motif made a rotation to form q and to complete the image. Through translation, the pattern was formed. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

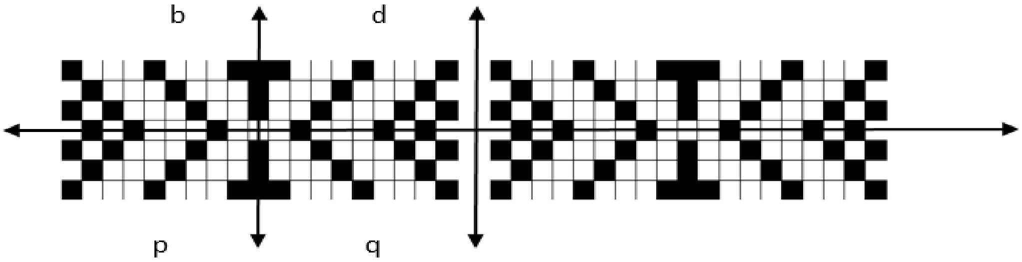



Figure A.3.2.1: Frieze Group Pattern Formed by Arrow and Triangle Designs in the "Majad" Attire

Figure A.3.2.1.1 shows the frieze group pattern formed by arrow and triangle design. The design made use of black arrows and black triangles embedded in either red or yellow background.

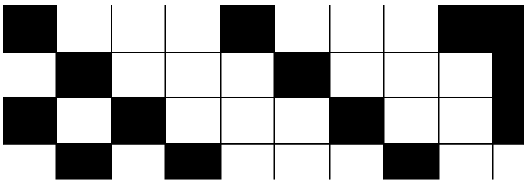


Figure A.3.2.1.1: Motif b of the Design Formed by the Arrow and Triangle Designs

Figure A.3.2.1.1 shows the motif of the pattern formed by arrow and triangle designs. Basing from the motif b, it made use of vertical and horizontal reflection to produce d and p. To complete the design, the motif b made a rotation to form q. Then, translation was also used to complete the pattern. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

**b. Kalanguya Attires**

**1. G – string (Kubal) for men**

Figure B.1: “Binuhlan”

Figure B.1 shows the common attire usually being used by the Kalanguya ethnic group as a G-string for men which is known as “BinuhIan”. It is designed using red, black or blue, white and yellow color of thread. The dominant color could be black or blue depending on the likeness of the weaver as long as the design is present. The frieze pattern formed in it is found at the near middle stripes similar with the “Pfinohlan” of the Ayangan attire.

For the analysis of the frieze group pattern of the cloth, see figure A.1.1.1 and figure A.1.1.1.1 from the Ayangan attires. Therefore, the frieze pattern formed by designs is p2mm (vertical and horizontal reflection with translation).

**2. Headband**

Figure B.2.1: “Penget”

Figure B.2.1 shows the upper headband adopted from the Tuwali ethnic group which is known as “Penget”. It made use of red, black and white color and a frieze pattern using men and rhombus design was formed in it using the black and white color.

Figure B.2.2: “Hinalibubu”

Figure B.2.2 shows another headband known as "Hinalibubu". It is the customary headband distinct for the "Kalanguya" ethnic group. It is being used by wrapping around the forehead and can be combined with a head of a bird or the horn of carabao. The attire made use of red and white stripes with frieze pattern of black sun design embedded in red and white backgrounds.

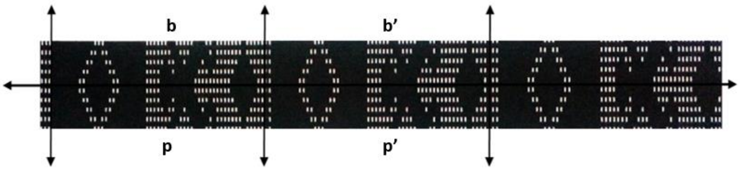



Figure B.2.1.1: Frieze Group Pattern Formed by Men and Rhombus Designs in the "Penget" Attire

Figure B.2.1.1 shows the frieze group pattern formed by men and rhombus design found at the middle stripe of the cloth. The design made use of black men and black and white rhombus to form the pattern.

Fig. B.2.1.1.1: Motif b of the Design Formed by Men and Rhombus design

Figure B.2.1.1.1 shows the pattern formed by men and rhombus design. Basing from the motif b, the design used horizontal reflection to produce p and to complete the image. Then, translation was made to form b' and p' and also to complete the pattern. Therefore, the frieze pattern is p11m (horizontal reflection and translation).


Figure B.2.2.1: Frieze Group Pattern Formed By Sun Design in the "Hinalibubu"

Figure B.2.2.1 shows the frieze group pattern formed by sun design found at the red and white stripes. The design made use of black sun enclosed in a hexagonal shape.

Figure B.2.2.1.1: Motif b of the Frieze Pattern Formed by Sun Design

Figure B.2.2.1.1 shows the motif of the pattern Using Sun design. Motif b made use of horizontal reflection to produced p and vertical reflection to produced d. Then, rotating the motif b, q was formed and the image of the sun was completed. Afterward, translation was being used to form the other image and to make the pattern. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

### 3. Skirt for women

Figure B.3: "Ampuyao"

Figure B.3 shows the skirt attire known as "Ampuyao" and it was borrowed by the Kalanguya from the "Tuwali" ethnic group. It was designed using black, white, and red stripes with two frieze group pattern being formed using rhombus and triangle shape.

There were also other attire being used by the "Kalunguya" ethnic group but were derived from other provinces and it was not usually used by the people.

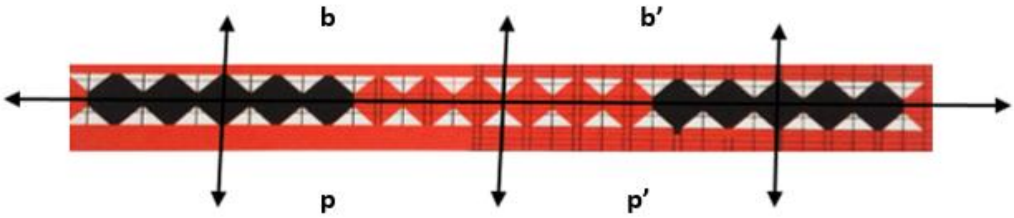



Figure B.3.1: Frieze Group Pattern Formed by Rhombus Design in the "Ampuyao" Attire

Figure B.3.1 shows the frieze group pattern formed by rhombus design that was found at the three red stripes of the cloth. The design consists of five black joint rhombuses connected with six red joint rhombuses. The color is given much importance in the design.

Figure B.3.1.1: Motif b of the Design Formed by Rhombus Design

Figure B.3.1.1 shows the motif of the pattern formed by rhombus design. Basing from the motif b, the design made use of horizontal reflection to produce p and to complete an image. Then, translation was used to form b' and p' and also to produce the pattern. Therefore, the frieze pattern is p11m (horizontal reflection and translation).

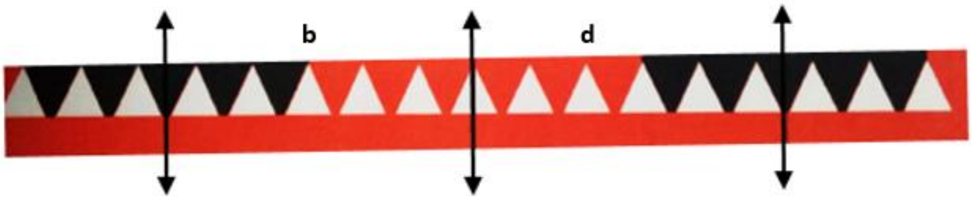



Figure B.3.2: Frieze Group Pattern Formed by Triangle Design in the “Ampuyao” Attire

Figure B.3.2 shows the frieze group pattern formed by triangle design found at the edge of the cloth. The designs consist of black and red background with aligned white triangles. It is the color in this design that is given much importance.

Figure B.3.2.1: Motif b of the Design Formed by Triangle Design

Figure B.3.2.1 shows the motif of the pattern formed by the triangle design. Motif b had a vertical reflection to form d. Then, translation was used to form the pattern. Therefore, the frieze pattern is p1m1 (vertical reflection and translation).

**4. Women’s belt**

Figure B.4: “Mayad”

Figure B.4 shows the women’s belt known as “Mayad”. The attire made use of red and yellow designs attached to a black background. This attire is the same with the “Majad” of the “Ayangan” attire.

For the analysis of the frieze pattern, see figure A.3.2.1 and figure A.3.2.1.1 of the “Ayangan” attire. Therefore, the frieze group pattern formed is p2mm (vertical and horizontal reflection with translation).

**c. Tuwali Attire**

**1. G – string (Wanoh) for men**

Figure C.1.1: Kargada (3 opad)

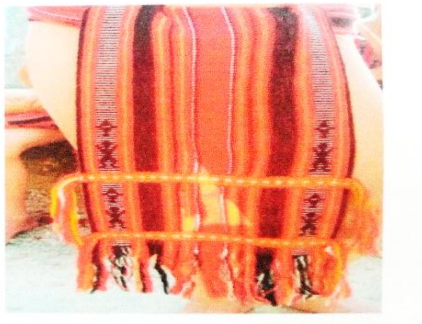


Figure C.1.2: Kargada (2 opad)

The above figures show the G-string for men which were known as "Kargada", though it is commonly known by the name of "wanoh" for the entire "Tuwali" ethnic group. Traditionally, the wealth of a person were determined by the number of horizontal design ("Opad") ranging from 1-3 but at present time, only attire with two or three horizontal design have survived. The cloths have colorful designs which include black, red, yellow, and white stripes. Two frieze patterns were also present on the stripes which use men design and rhombus design.


Figure C.1.1.1 Frieze Group Design Formed by Arrow and Rhombus Design in the "Kargada" Attire

Figure C.1.1.1 shows the frieze group pattern formed by the rhombus design found at the horizontal design of the cloth. The design uses yellow lines combined with white color and embedded in a red background to form the pattern.

Figure C.1.1.1.1 Motif b of the Design Formed by Arrow and Rhombus Design

Figure C.1.1.1.1 shows the motif of the pattern formed by arrow and rhombus design. Motif b uses horizontal and vertical reflection to produced p and d, respectively. Then, rotation was made by motif b to produce q and to complete the image. Translation was also done to make the pattern. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

For analysis of the other frieze group pattern present on the cloth, see figure I.A.1, figure I.A.1a, figure I.C.2a, and figure I.C.2a of the “Ayangan” attires. Therefore, the other frieze pattern formed is p11m (horizontal reflection and translation).

## 2. Headband

Figure C.2: “Pongot”

Figure C.2 shows the headband for men known as “Pongot”. The attire may have or may not have frieze group pattern of men design which is usually found at the middle stripe of the cloth. The attire uses black, red, and yellow or white color depending on the weavers’ style.

For the analysis of the frieze group pattern formed, see figure B.2.1.1, and figure B.2.1.1.1 of the “Kalanguya” attires. Therefore, the frieze pattern formed is p11m (horizontal reflection and translation)

## 3. Skirt (To-ge) for Women

Figure C.3.1: “Napagawa-an”

Figure C.3.1 shows skirt attire worn by the upper class women known as “Napagawa-an”, traditionally. The design of the cloth is the same with the “Baya-ung” blanket only it has a designed white panel at the middle stripe of the cloth. At present, this attire can be worn by anybody.

Figure C.3.2: “Bayya-ung”

Figure C.3.2 shows the most common attire and traditionally worn by the middle class women. It is known as "Bayya-ung" that has the same design with the "Bayya-ung" blanket.

Figure C.3.3: "Ampuyoh"

Figure C.3.3 shows the third type of skirt known as the "Binnalit". Traditionally, it is worn by poor women. This attire is exactly the same with the "Ampuyao" skirt of the "Kalanguya" attires.

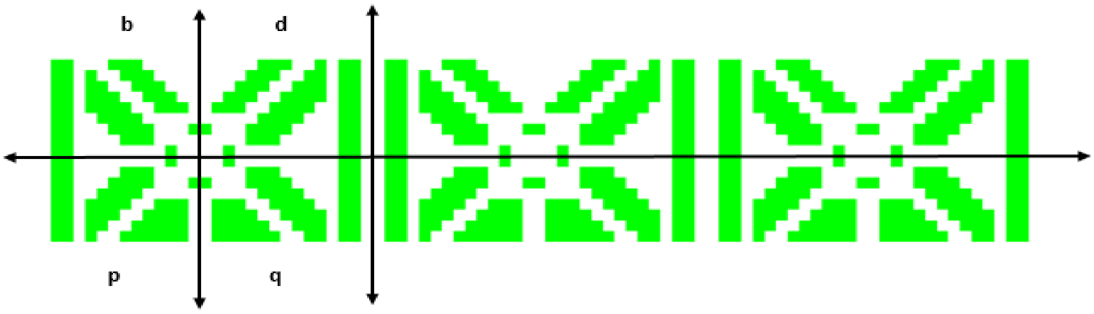



Figure C.3.1.1: Frieze Group Pattern Formed by Flower Design in the "Napagawa-an" Attire

Figure C.3.1.1 shows the frieze group Pattern formed by the flower design found at the designed white panel of the cloth. The design of the flower is either colored green or yellow.

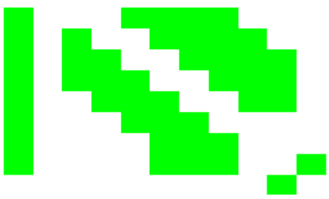


Figure C.3.1.1.1: Motif b of the Design Formed by Flower Design

Figure C.3.1.1.1 shows the motif of the pattern formed by flower design. Basing from the motif b, the design used horizontal reflection and vertical reflection to produced p and d, respectively. Then, the motif also made a rotation to form q and to complete the flower image. Through translation, the pattern was formed. Therefore, the frieze pattern is p2mm (vertical and horizontal reflection with translation).

For the analysis of the other frieze pattern formed in the skirts attire, see figure A.2.2.1 and figure A.2.2.1.1 of the "Ayangan" attires and figure B.3.1, figure B.3.1.1, figure B.3.2, and figure B.3.2.1 of the “Kalanguya” attires. Therefore, the other frieze pattern formed is p11m (horizontal reflection and translation) and p1m1 (vertical reflection and translation).

### 4. Blouse for women

Figure C.4: “Lamma”

Figure C.4 shows the two style of the blouse for women known as “Lamma”. This attire is a modern adaptation for upper cloth attire of women. It is purely white in color with designs at the edges of the cloth. The designs depend on the weavers’ style. Frieze pattern using triangle design was present at the edges of the cloth.

For the analysis of the frieze group pattern present on the cloth, see figure B.3.2 and figure B.3.2.1 of the “Kalanguya” attires. Therefore, the pattern is p1m1 (vertical reflection and translation).

### 5. Women’s belt

Figure C.5: “Boa-koh”

Figure C.5 shows the womens belt known as “Boa-ah”. It is the same with the “Majad’ of the “Ayangan” attires or the “Mayad” of the “Kalanguyu” attires. For the analysis of the frieze pattern, see figure A.3.2.1 and figure A.3.2.1.1 of the “Ayangan” attire. Therefore, the frieze group pattern formed is p2mm (vertical and horizontal reflection with translation).

## BALANGAO

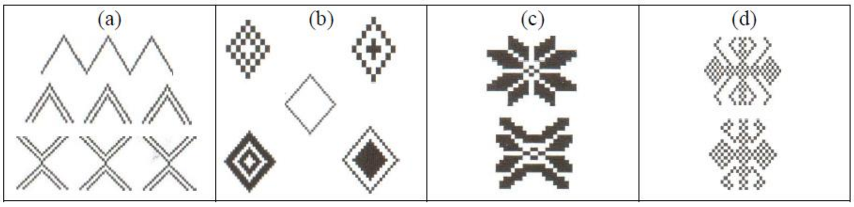



Figure 1 depicts the most frequent patterns on Kankana-ey fabrics: tiktiko (a), matmata (b), sopo (c), and kulibangbang (d).

In Figure 1, popular designs such as tiktiko, matmata, sopo, and kulibangbang are combined to produce Kankana-ey patterns on textiles. These design patterns and motifs honor the Kankana-respect ey's for their natural surroundings and their harmonious connections with the environment (the joys, the revelry, attendant to fertility and abundance/bountiful harvest). Their villages, which are located on mountain crests and deep valleys, are characterized by zigzag tiktiko patterns, which are believed to symbolize the mountains and forests that surround their rice fields. The X's tiktiko and matmata symbolize plenty, reverence, awe, and high regard for whatever the X's and's signify. These X's tiktiko represent rice mortars since they are shaped like their rice mortars, whether carved in stone or wood. Because rice sustains their bodies, they adored and worshiped it as a god who is omnipresent and all-seeing, which is why the double-matmata lined's are thought to represent rice grains and eyeballs. Due to the fact that the combination of X's tiktiko and matmata symbolizes wealth and plenty, these designs are reserved for the rich's clothing. Flora and fauna are used to symbolize plenty, fertility, and wealth, with the sopo resembling a flower and the kulibangbang like a butterfly.

**a. TAPIS AND ULES**

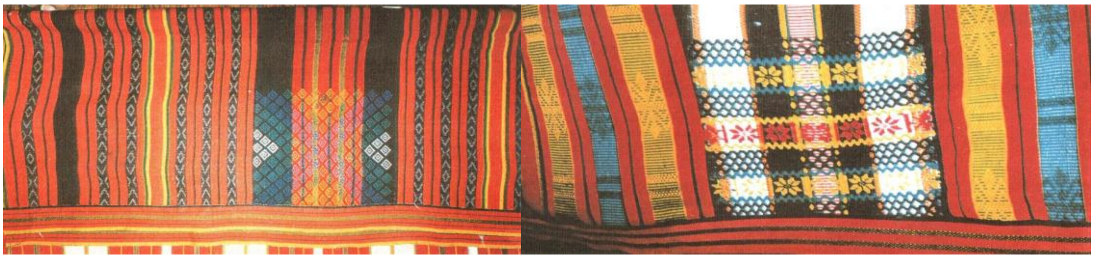
The ules are used to protect the body of the Kankana-top ey from the environment. The blanket is made up of red and blue panels of varying lengths that include brickwork patterns or anthropomorphic figures. When children are six or seven years old, they are first given ules for covering and then begin wearing their own wanes or tapis.

An ules or tapis is a woven clothing panel comprised of three similar side panels and a central panel. The combinations of X, (tiktiko), and (matmata) on the vertical strip patterns on the side panels of the ules or tapis are shown in Figures 5 (a), (b), and (c) (c). Each of these vertical strip designs has symmetrical vertical and horizontal reflections. (Figure 6 (a) illustrates several reflection axes and their intersections as 180-degree rotating centers.) Strip patterns with vertical and horizontal reflections belong to the symmetry group pmm2. The horizontal strip pattern in the middle panel of the textiles in Figures 5 (a), (b), and (d), which incorporates a zigzag tiktiko, matmata, and sopo, also contains vertical and horizontal reflection symmetries; therefore, it belongs to the pmm2 symmetry group. The axes of reflection and the centers of 180o rotations are shown in Figures 6 (b), (c), and (d) on a strip pattern.

When the pattern on the ules and tapis in the middle panel is interpreted as a two-dimensional repeating pattern, a symmetry group of type pmm or p4m is usually obtained. For the patterns shown in Figures 5 (a), (b), and (c), there are symmetries consisting of vertical and horizontal reflections with perpendicular axes (d). Additionally, there exist 180° rotations with centers on reflection axes (see Figures 7 (a), (b), and (c) for examples). As a consequence, these designs belong to the pmm symmetry group. The two-dimensional pattern shown in the middle panel of Figure 5 (c) has the symmetry group p4m. Figure 7 (d) illustrates a 90-degree rotation and reflections with the axes crossing at a 45-degree angle.

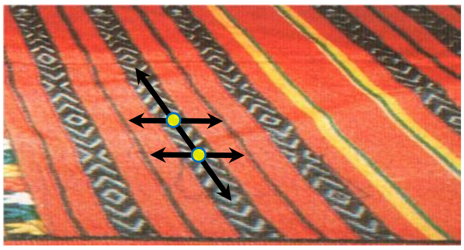
It is worth noting that while examining the symmetry groups of the designs, we assume that the patterns repeat vertically or horizontally inside a particular panel, even though they seem to be of finite length in the resulting ules or tapis. Additionally, we analyze the symmetry group independently of the pattern's color; that is, we study the symmetry groups of the uncolored pattern on the fabric. For instance, in Figure 5, we disregard the two strong vertical black hues in the middle panel (b). The same assumptions apply when analyzing the symmetry of the designs on the other fabrics in this study.

(a) (b)

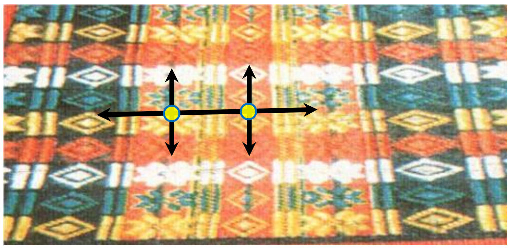


(c) (d)

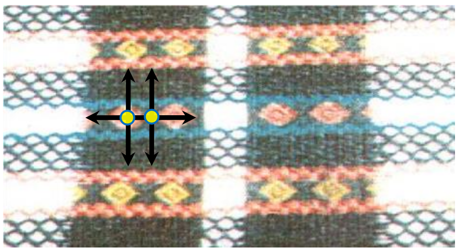
**Figure 5**: Various patterns on a tapis or ules [6].



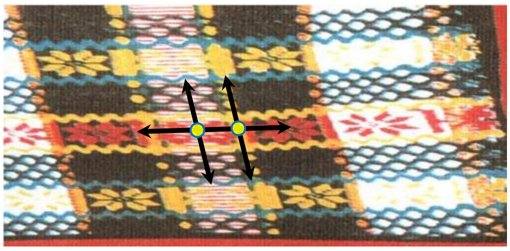
(a)



(b)

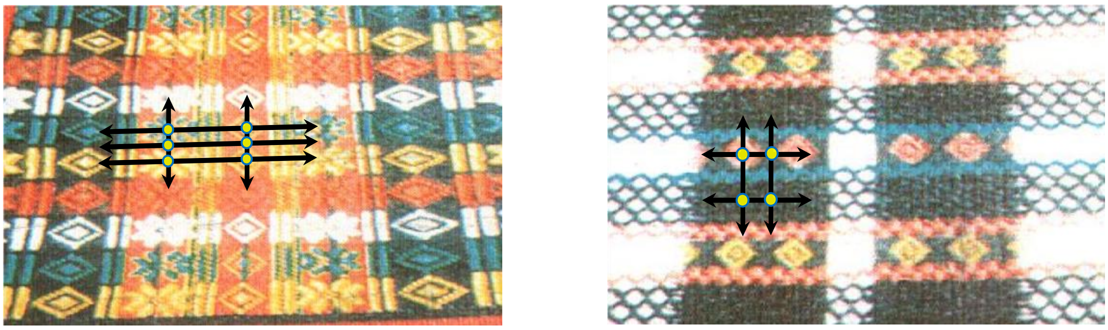


(c)



(d)

Figure 6: The reflection axes and rotational symmetry centers on the ules/tapis.



(a) (b)

(b) (d)

Figure 7: Reflection axes and rotational symmetry centers for the designs in Figure 5.

## b. THE BAKGET OR WAKES

Typically, a wakes or bakget is used to secure the tapis, which is a piece of cloth about 7.5-10 cm wide that is wrapped twice around the waist. On a daily basis, Kankana-ey women wear wakes, while the bakget is saved for special events or ceremonies. Women wear wakes after birth to support their stomach and pelvic muscles, preventing them from sagging and ensuring them walk tall and erect.

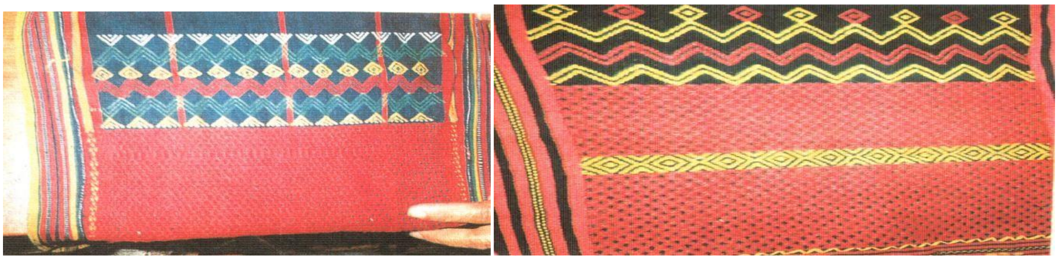
The horizontal reflection symmetry of the tiktiko strip patterns that often appear in wakes (an example is illustrated in Figure 8 (a)). Thus, the symmetry group of the horizontal strip pattern is p1m1. On the other hand, each vertical strip design on the bagket (see Figure 8 (b)), which is often comprised of sopo and zigzag tiktiko, has both vertical and horizontal reflections and is a member of the symmetry group pmm2. The axes of reflectional symmetry and rotational centers for different strip pattern examples are shown in Figure 9.


**Figure 8**: Strip patterns seen on (a) wakes and (b) bakget.


**Figure 9**: The axes of reflection and the centers of rotational symmetries on the strip patterns in Figure 8

**THE WAREHOUSE**

The wanes or g-string, a woven cloth wrapped around the waist and hanging down to conceal the loins, is the Kankana-ey men' traditional dress. This outfit is currently only used at ceremonial gatherings and on rare occasions. The wanes are often brightly colored with red stripes, but they may also be dark blue with red stripes and ornamented ends. The embellished ends of the wanes (as shown in Figure 10) are often comprised of zigzag tiktiko and matmata strip patterns. By excluding the vertical strips at the wanes' borders and assuming that the strip patterns extend indefinitely on both ends, we deduce that the symmetry group of these strip patterns is pm11. Vertical reflections with axes separated by half the length of the translation are included in these patterns. The axes pass through the cores of the matmata and link them to one another. Occasionally, as shown in Figure 10, we observe an additional strip pattern running horizontally along the middle of a wanes. (b). This design combines a variation on tiktiko and matmata with a symmetry group of type pmm2. Figure 11 illustrates the axes of reflection and rotation of the strip patterns' symmetries.



(a) (b)

**Figure 10**: On wanes, there are many patterns

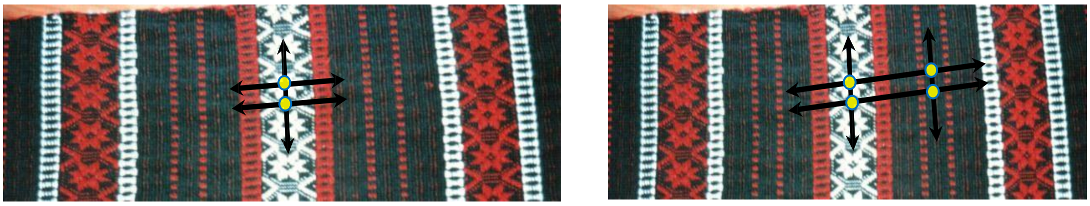
(a) (b)

**Figure 11**: Axes of reflection and rotational symmetry centers on Figure 10 patterns

**a. BEDBED** (males cover their short)

Male Kankana-eys cover their short hair with abel (cloth) or kuba (bark) bedbeds embellished with feathers, leaves, and even carabao horns. Figure 12 depicts a typical bed design. Each vertical strip is a hybrid of sopo and tiktiko with a symmetry group of type pmm2. Combining these strip patterns results in a two-dimensional design with pmm symmetry. The axes of reflection and the centers of rotational symmetries are shown in Figure 13.

Fig. 12: Bedbed patterns



(a) (b)

**Figure 13**: Axes of reflection and rotational symmetry centered on bedbed patterns in Figure 12.

**The Patterns' Color Symmetries**

As a short overview of the Kankana-ey textiles' color symmetries, we found that the bulk of the weave patterns studied in the study are multicolored, with just a few examples of two-color patterns.

Not only do we study the symmetrical pattern itself in color symmetry theory, but also the many methods in which the pattern may be colored symmetrically. A colored symmetrical pattern is frequently associated with three groups [1]: the group G, which sends the uncolored pattern to itself, the subgroup H of G, which contains elements that affect color permutation, and the subgroup K of H, which contains elements that fix the colors in the given coloring. Due to their association with a certain color, the groups H and K are referred to as the color group and color fixing group, respectively. If H = G, the pattern's coloring is considered to be perfect. Otherwise, the coloring is described as poor or inconsistent. Perfect coloring is characterized by an equal distribution of colors across the colored pattern.

We assume for the textiles detailed in this note that the designs are either a strip pattern or a two-dimensional pattern with the uncolored pattern's symmetry group being a frieze group or a plane crystallographic group, as previously indicated. As can be seen, all of the resulting strip patterns are exactly colored, with the symmetry group G serving as both the color group and the color fixing group. The stripe pattern seen in the upper portion of Figure 10's wanes is an exception (b). This is a non-perfect coloring in which reflections with axes crossing through neighboring matmatas exchange the matmata's red and yellow colors and fix the tiktiko's red and yellow colors (the reflection with the leftmost axis in the top half of Figure 11(b) corresponds to such a reflection). As a consequence, the coloring is uneven or poor.

We have excellent colorings for the patterns shown in Figures 5 (a) and (b), but not for the patterns depicted in Figures 5 (c) and (d) (d). In the pattern shown in the middle panel of Figure 5, there are more green matmatas than white matmatas (c). Vertical reflections therefore stabilize certain green matmatas while simultaneously interchanging green and white matmatas (see Figure 7(d)). The pattern displayed in the middle panel of Figure 5 (d), which alternates red and yellow sopo and blue and yellow tiktiko, has a horizontal reflection (see Figure 7 (c)). As a consequence, the colour supplied is inconsistent.On the bedbed, the two-dimensional colorful pattern is likewise a flawlessly colored pattern.

1. G – string for Men


Figure B.1: “Taye’y”

Figure B.1 shows the g – string of the efiarangao men known as “taye’y”. It is an elongated cloth consist of dark red and red stripes with yellow stripes at the end of the cloth and tassels at both ends to beautify it.

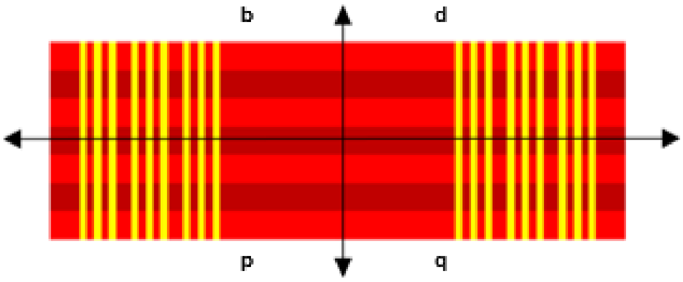



Figure B.1.1: Frieze Group Pattern Formed by Rectangular Design at the “Taye’y” attire

Figure B.1.1 shows the frieze group pattern using rectangular designs that was formed at the edge of the cloth. The vertical stripes and horizontal stripes intersect creating perpendicular lines. Thus, frieze group pattern is formed.

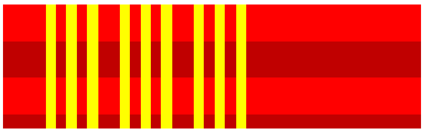


Figure B.1.1.1: Motif b of the Design formed by Rectangular Design

Figure B.1.1.1 shows the motif of the pattern formed by rectangular design. Motif b had a horizontal reflection to produce p and vertical reflection to produce d. The motif also had a rotation to produce q to complete the image. Therefore, the frieze pattern is p2mm (reflection over horizontal line and vertical line with translation).

2. Skirt for Women


Figure B.2: "Petay"

Figure B.2 shows the skirt of the Efiarangao women known as "Petay". The skirt is consisted of red and blue horizontal stripes with parallelogram design embedded at the blue stripe found at the center of the cloth. The right and left edge of the skirt contains square design connected with each other making it aligned vertically.

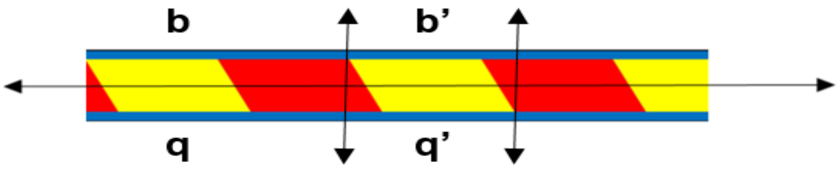



Figure B.2.1: Frieze Group Pattern Formed by Parallelogram in the "Petay" attire

Figure B.2.1 shows the parallelogram design embedded at the blue stripe of the petay. The parallelograms are connected with each other making them align horizontally. The parallelograms are in color yellow and red and are aligned alternately.

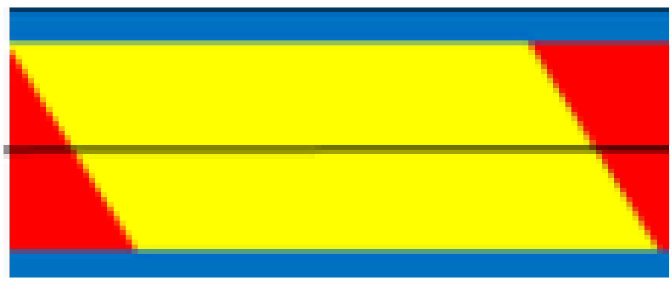


Figure B.2.1.1: Motif b of the Design Formed by the Parallelogram Design.

Figure B.2.1.1 shows the motif formed by parallelogram design. The motif b made a half turn (rotation) to produce q. then, the design formed by band q was repeated through translation to produce the whole pattern. Thus, the frieze pattern is p2 (rotation and translation).

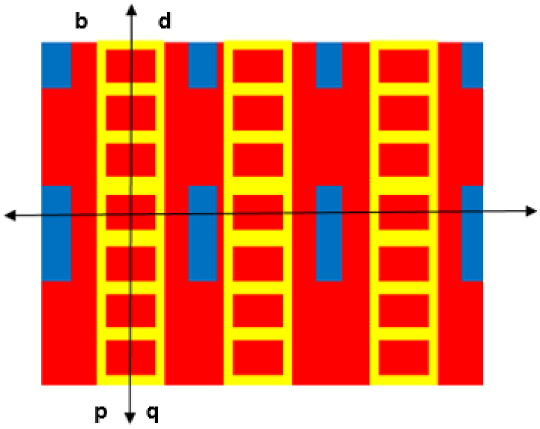



Figure B.2.2: Frieze Group Pattern Formed by Box Design in the "Petay" attire

Figure B.2.2 shows the square design found at the right and left side of the petay. The squares are yellow in color and are connected with each other making it align vertically. Besides the squares are horizontal red linings.

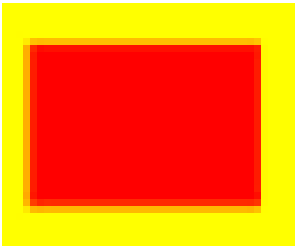


Figure B.2.3: Motif b of the Design Formed by Box Design

Figure B.2.3 shows the motif of the pattern using box design. Motif b made a vertical reflection to produce d and horizontal reflection to produce p. Then motif b made a 2-fold rotation to produce q. The translation is also used to complete the pattern. Therefore, the frieze group pattern was p2mm (vertical and horizontal reflection with translation).

3. Belt for Women


Figure B.3: "Felekos"

Figure B.3 shows the belt of the Efiarangao women known as "Felekos". It is an elongated cloth consist of blue, red and yellow stripes with arrow designs.

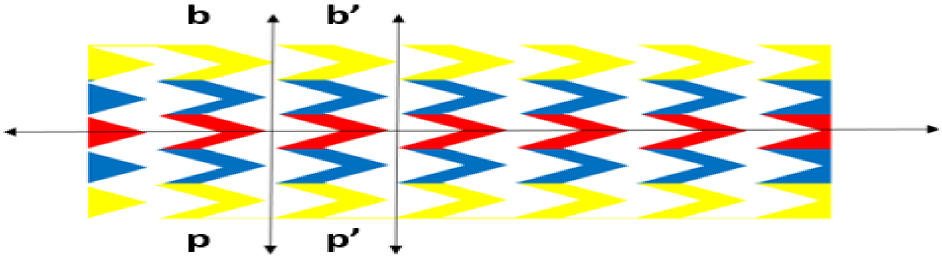



Figure B.3.1: Frieze Group Pattern Formed by Arrow Design in the "Felekos" attire

Figure B.3.1 shows the frieze group pattern found at the elongated cloth which was formed by arrow design. The arrows were embedded at the stripes of the cloth.

Figure B.3.2: Motif b of the Frieze Group Pattern of the Arrow Design in the Felekos

Figure B.3.2 shows the motif of the pattern formed by arrow design. Motif b had a horizontal reflection forming p. Then b' and p' were formed through translation from b and p. Then the translation continued to complete pattern. Therefore, the frieze pattern is p11m (reflection over a horizontal line and translation).

## A. GA'DANG

Figure C shows the Ga'dang with their native attires

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Ga'dangs are very rich in culture. Their native attires are so colorful with lots of beads. And what makes it so fascinating is the fact they are all handmade. It only shows how patient, hardworking and artistic the Ga'dangs are.

**1. G – string for Men**

Figure C.1: "Abag"

Figure C.1 shows the g – string of the Ga'dang men known as "Abag". It is an elongated cloth consist of red, yellow, white and black stripes with beads embedded at each edge of the elongated cloth making it look so colorful and artistic.

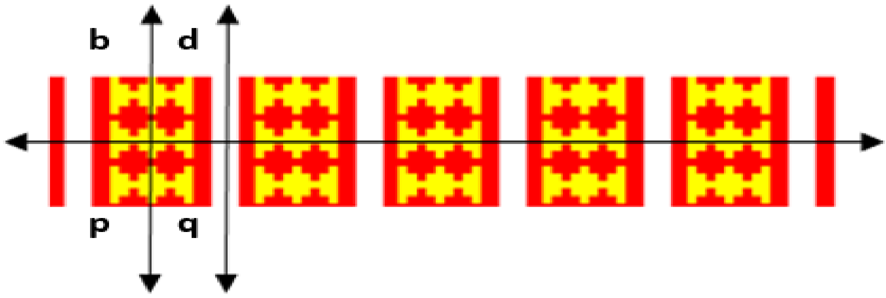


Figure C.1.1: Frieze Group Pattern Formed by Triangle and Rhombus Designs in the "Abag"

Figure C.1.1 shows the frieze group pattern formed by triangle and rhombus designs. The design made use of yellow beads formed by a rhombus connected with triangle at the right and left edge of the rhombus design.

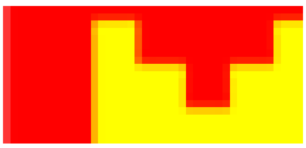

Figure C.1.3: Motif b of the Design Formed by Triangle and Rhombus Designs

Figure C.1.3 shows the motif of the pattern formed by triangle and rhombus designs. Motif b had a horizontal reflection to produce p and vertical reflection producing d. Motif b had a 2 –

fold rotation forming q. Then, translation was also used to complete the pattern. Therefore, the frieze pattern is p2mm (reflection over vertical line and horizontal line with translation).

Figure C.1.4: Frieze Group Pattern Formed by Double X Design in the "Abag"

Figure C.1.4 shows the frieze group pattern formed by Double X design in the abag. The frieze group pattern is formed at the upper and lower part of the elongated cloth.

Figure C.1.5: Motif b of the Design Formed by Double X Design

Figure C.1.5 shows the motif of the pattern formed by double X. Motif b had a horizontal reflection to produce p and a vertical reflection forming d. Then, motif b made a 2 – fold rotation or half turn to produce q. Through translation, the whole pattern was formed. Thus the frieze pattern is p2mm (reflection over a vertical line and horizontal line and translation).

**2. Cape for Men**

Figure C.2: "Kapit"

Figure C.2 shows the cape of the Ga'dang native attire for men known as "Kapit". It is a rectangular piece of cloth that is made up of red, yellow, black, white and gray stripes with beads at the right and left of the kapit. The upper edge of the kapit contains red and yellow threads with beads that is used to tie both ends of the kapit.

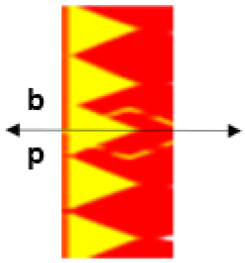


Figure C.2.1: Frieze Group Pattern Formed by Triangle Design

Figure C.2.1 shows the frieze group pattern formed by triangle design found at the edge of the cloth. The triangles are embedded at the stripes of the cloth.

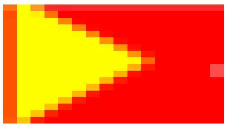

Figure C.2.1.1: Motif b of the Design formed by Triangle Design

Figure C.2.1.1 shows the motif of the pattern formed by triangle design. Motif b made a horizontal reflection producing p. Then, translation is used to complete the pattern. Thus the frieze pattern is p11m (horizontal reflection with translation).

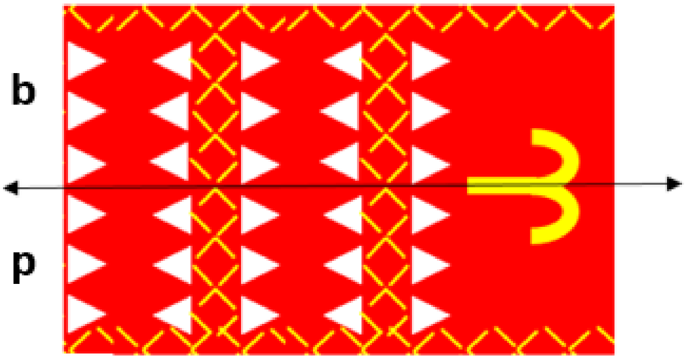


Figure C.2.2: Frieze Group Pattern Formed by Triangle and Rhombus Design

Figure C.2.2 shows the frieze group pattern formed by triangle and rhombus design found at the edge of the cloth. The triangles are made up of white beads while the rhombus are made up of thread formed into rhombus design.

Figure C.2.2.1: Motif b of the Design Formed by Triangle and Rhombus Design

Figure C.2.2.1 shows the motif of the pattern formed by triangle and rhombus design. The motif b uses horizontal refection to produce p. Translation is also used to produce the pattern of the cloth. Therefore, the frieze pattern is p11m (horizontal reflection and translation).

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### 3. Vest for Men

Figure C.3: "Koton"

Figure C.3 shows the vest for Ga'dang men also known as "Koton". The koton serves as the upper cloth of the men. It is made up of a red cloth as a background with stripes embedded on it. Beads are also present on the cloth to make it more stunning and pleasing in the eyes.

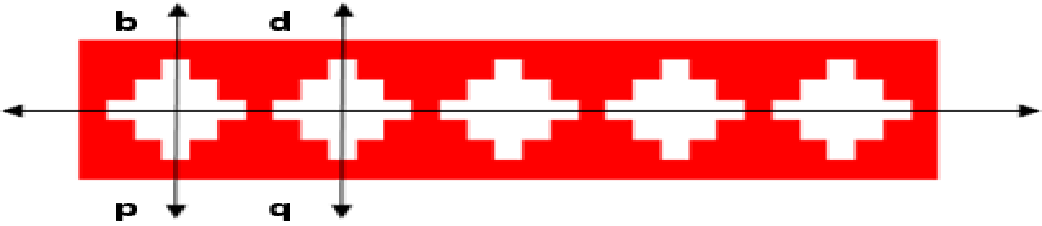


Figure C.3.1: Frieze Group Pattern Formed by Rhombus Design in the "Koton" attire

Figure C.3.1 shows the frieze group pattern formed by rhombus design. The design is made up of white beads embedded on the stripes of the cloth and are aligned vertically following the line of our spinal cord. The design is can be found at the back of the cloth.

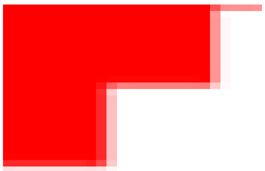

Figure C.3.1.1: Motif b of the Design Formed by Rhombus Design

Figure C.3.1.1 shows the motif of the design formed by rhombus design. The motif b made a vertical and horizontal reflection to produce d and p. It also made a 2 – fold rotation forming q. Then, translation is also made to complete the pattern. Therefore, the frieze group pattern is p2mm (vertical and horizontal reflection with translation).

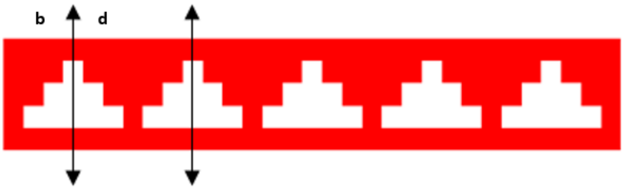


Figure C.3.2: Frieze Group Pattern Formed by Triangle Design in the “Koton” attire

Figure C.3.2 shows the frieze group pattern formed by triangle design. The design is made up of white beads embedded on the stripes of the cloth. The beads are aligned at the edge of the cloth emphasizing the shape of the cloth.

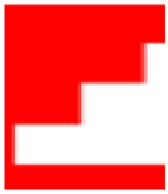

Figure C.3.2.1: Motif b of the Design Formed by Triangle Design

Figure C.3.2.1 shows the motif of the design formed by triangle design. Motif b made a vertical reflection to produce d. Then translation is used to complete the pattern. Thus, the frieze group pattern is p1m1 (vertical reflection and translation).

**4. Skirt for Women**

Figure C.4: “Aken”

Figure C.4 shows the skirt of the Ga’dang women known as “Aken”.It is a combination of color red, black and white with beads embedded within it. The color red dominated the skirt. Both sides of the skirt have beads to beautify the skirt.

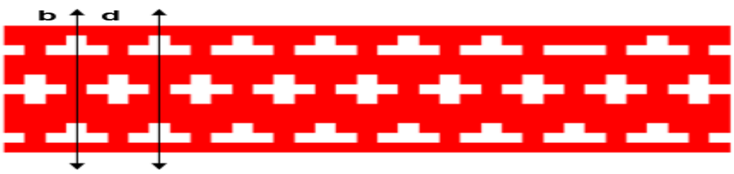


Figure C.4.1: Frieze Group Pattern Formed by Triangle and Rhombus Designs in the “Aken” attire

Figure C.4.1 shows frieze group pattern formed by triangle and rhombus designs. The triangles are made up of white beads embedded on the red little stripes and are aligned horizontally. The rhombus designs are also made up of white beads embedded on the black stripes of the cloth.

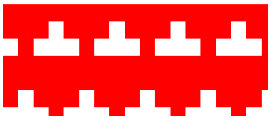

Figure C.4.1.1: Motif b of the Design Formed by Triangle and Rhombus Design

Figure C.4.1.1 shows the motif of the pattern formed by triangle and rhombus design. Motif b made a vertical reflection to produce d. Then, translation was also used to complete the pattern. Thus, the frieze group pattern is p1m1 (vertical reflection with translation).

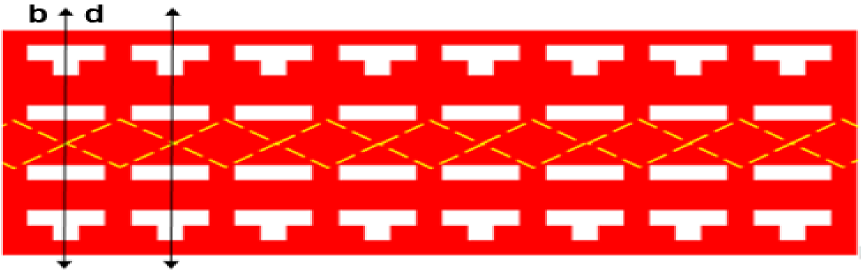


Figure C.4.2: Frieze Group Pattern Formed by Triangle and Rhombus Design

Figure C.4.2 shows the frieze group pattern formed by triangle and rhombus design. The triangles are made up of white beads embedded between the black and red stripes. The rhombuses are made up of red and yellow threads.

Figure C.4.2.1: Motif b of the Design Formed by Triangle and Rhombus Designs

Figure C.4.2.1 shows the motif of the pattern formed by triangle and rhombus designs. Motif b made a vertical reflection to produce d. Then translation is also used to complete the pattern. Therefore, the frieze pattern is p1m1 (vertical reflection with translation).

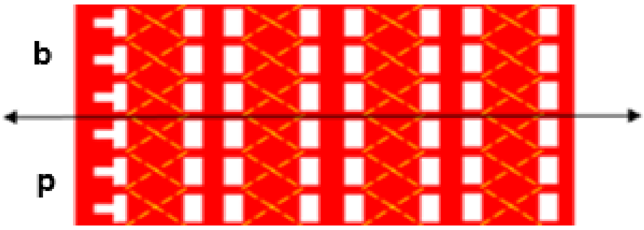


Figure C.4.3: Frieze Pattern Group Formed by Rhombus, Rectangle and Triangle Designs in the "Aken"

Figure C.4.3 shows the frieze pattern group formed by rhombus, rectangle and triangle designs in the edge of the aken. The rectangle and triangle frieze group pattern are made up of white beads embedded on the edge of the aken. The rhombus design is embedded between the rectangle design and the triangle design.

Figure C.4.3.1: Motif b of the Frieze Pattern formed by the Rhombus, Rectangle and Triangle Designs

Figure C.4.3.1 shows the motif of the pattern formed by rhombus, rectangle and triangle designs. Motif b made a horizontal reflection producing p. The process continued until the whole pattern was formed. Therefore, the frieze group pattern is p11m (horizontal reflection and translation).

**5. Women's Belt**

Figure C.5: "Bacuat"

Figure C.5 shows the belt of the Ga'dang women known as "Bacuat". The belt is also red in color with beads. The bacuat has two sides. Only the other side of the bacuat has beadswork on it so that if they will wear it, only the side with beads will show. Both ends of the bacuat also have lots of beads to beautify it.

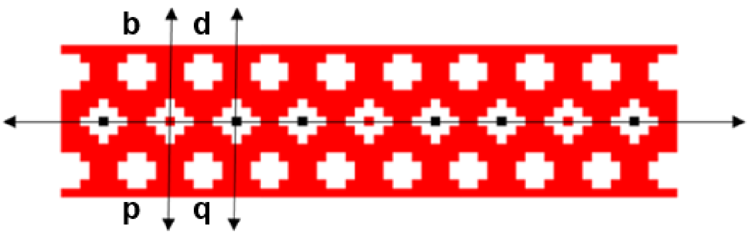


Figure C.5.1: Frieze Group Pattern Formed by Rhombus Design at the "Bacuat" attire

Figure C.5.1 shows the elongated part of the belt with red, yellow and black stripes. The frieze patterns are made up of white beads that are embedded at the top, middle and bottom of the cloth. The beads were formed in a rhombus shape.

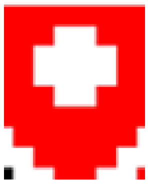

Figure C.5.1.1: Motif b Formed by Rhombus Design

Figure C.5.1.1 shows the motif of the pattern using rhombus design. The motif b had a horizontal and vertical reflection producing p and d respectively. Then, a rotation is made to create q. Therefore, the frieze group pattern is p2mm (vertical and horizontal reflection with translation).

Figure C.5.2: Frieze Group Pattern Formed by X Design in the "Bacuat" attire

Figure C.5.2 shows the frieze group pattern found at the edge of the belt. It consists of beads with different colors making it look so colorful. The beads formed into X with horizontal linings at the top and bottom.

Figure C.5.2.1: Motif b of the Frieze Pattern Formed by X Design

Figure C.5.2.1 shows the motif of the pattern formed by X design. The motif b made a vertical reflection producing d. Then, translation is used to complete the pattern. Therefore, the frieze group pattern is p1m1 (reflection over vertical line and translation).

## 6. Blouse for Women

Figure C.6: “Barwasi”

Figure C.6 shows the blouse for ga’dang women also known as “Barwasi”.

Figure C.6: “Barwasi”

Figure C.6 shows the blouse for Ga’dang women known as “Barwasi”. The blouse is made up of red cloth with white and yellow beads attached to it creating frieze patterns.

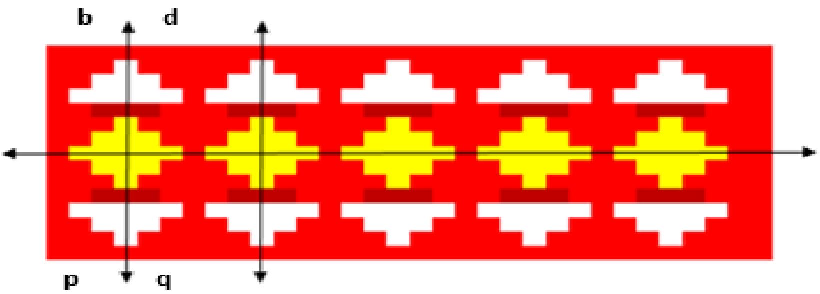


Figure C.6.1: Frieze Group Pattern Formed by Triangle and Rhombus Design

Figure C.6.1 shows the frieze group pattern formed by triangle and rhombus design. The design can be found at the different part of the cloth. The triangles are made up of white beads and the rhombus is made up of yellow beads.

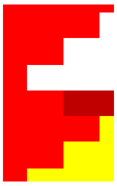

Figure C.6.1.1: Motif b of the Design Formed by Triangle and Rhombus Design

Figure C.6.1.1 shows the motif of the pattern formed by triangle and rhombus design. The motif b made a vertical and horizontal reflection producing d and p. Then it made a 2 – fold rotation producing q. Translation is also used to complete the pattern. Thus, the frieze group pattern is p2mm (vertical and horizontal reflection with translation).

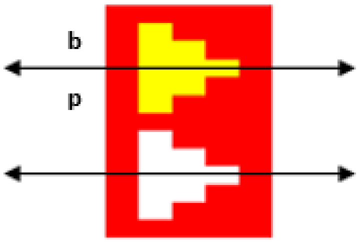


Figure C.6.2: Frieze Group Pattern Formed by Triangle Design

Figure C.6.2 shows the frieze group pattern formed by triangle design. The design is made up of two yellow beads and two white beads aligned vertically.

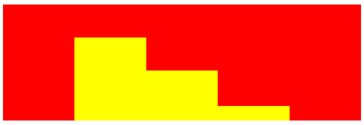

Figure C.6.2.1: Motif b of the Design Formed by Triangle Design

Figure C.6.2.1 shows the motif of the pattern formed by triangle design. The motif b made a horizontal reflection producing p. Then translation is used to complete the pattern. Therefore, the frieze pattern is p11m (horizontal reflection with translation).

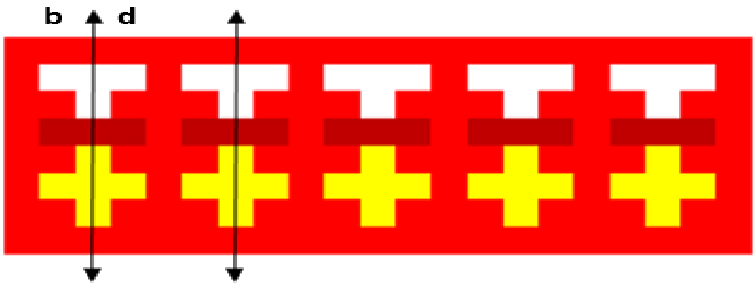


Figure C.6.3: Frieze group Pattern Formed by Triangle and Rhombus Design

Figure C.6.3 shows the frieze group pattern formed by triangle and rhombus design. The design is made up of white, yellow and red beads formed into triangle and rhombus design. The design can be found in the neck part of the cloth.

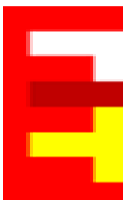

Figure C.6.3.1: Motif b of the Design Formed by Triangle and Rhombus Design

Figure C.6.3.1 shows the motif of the design formed by triangle and rhombus design. The motif b made a vertical reflection producing d. Then translation is used to complete the pattern. Therefore, the frieze pattern is p1m1 (vertical reflection with translation).

## VI. Conclusion

The presence of the five frieze patterns group p111 (translation only); group pmm2 (vertical and horizontal reflection with translation); group p1m1 (horizontal reflection and translation); group pm11 (vertical reflection and translation); group p112 (rotation and translation) was discovered in native woven attires from the three ethnic groups in Ifugao as an expansion of knowledge in the field of ETHNOMATHEMATICS (vertical reflection, glide reflection, and translation). The only frieze pattern that was regularly employed was the pmm2 frieze group pattern. The Ifugao weavers were able to construct five frieze group patterns, whereas the Ga'dang and Balangao weavers were able to produce three and four, respectively. The textiles of the three main ethnic groups' indigenous woven garments were found to be mostly longitudinally striped, with iconographic patterns organized into a system of well-defined formal connections. We discovered that the basic designs or motifs have intrinsic symmetries during our study on the symmetries and color symmetries of weaving patterns from the Eastern Cordillera. As a result, horizontal and/or vertical reflections became more common in their weaves. Additionally, weavers from the three major ethnic groups arranged these basic components symmetrically, creating one- or two-dimensional patterns on their cloth. We were fascinated by the weavers' method of crossing the various threads to create stunning symmetrical patterns. The inherent ideas of symmetry and order in the weaving patterns suggest the existence of an underlying mathematical structure that the Eastern Cordillera women weavers may be ignorant of. As a consequence, we've shown that mathematics is profoundly entrenched in the culture of humans. The patterns on the original woven garments were inspired by imagery seen in the surrounding or environment, such as flora, the sun, and man, among others that are culturally significant. Most designs were found in men's attires because priestess did not exist until now. In addition, there are unique frieze designs for men's clothing and for women's clothes. Costumes were obvious when each ethnic group had its own unique characteristics.

## VII. Recommendations

1. To utilize this study as an example for teaching lessons on the interaction between culture and mathematics in classrooms.
2. That this study will serve as an awareness of the beauty of the young people's attractions on the eastern cordillera or on the entire cordillera.
3. That the patterns collected in this study are conserved by the weavers of the eastern cordillera.
4. That this work is used as a reference for any relevant investigations.
5. Further investigations can be carried out in other Cordilleran native attires.

## VIII. Literature Cited


1. Albers, A., Weber, N. F., Cirauqui, M., & Smith, T. (2017). On weaving: new expanded edition. Princeton University Press.
2. Amit, M., & Qouder, F. A. (2017). Weaving Culture and Mathematics in the Classroom: The Case of Bedouin Ethnomathematics. In Ethnomathematics and its Diverse Approaches for Mathematics Education (pp. 23-50). Springer, Cham.
3. Balamurugan, M. (2015). Ethnomathematics; An Approach For Learning Mathematics From Multicultural Perspectives. International Journal Of Modern Research And Reviews, 3(6), 716-720.
4. Budiarto, M. T., Artiono, R., & Setianingsih, R. (2019). Ethnomathematics: Formal Mathematics Milestones for Primary Education. In Journal of Physics: Conference Series (Vol. 1387, No. 1, p. 012139). IOP Publishing.
5. Burns, K. (2013). The Media Surface of Design Reform: Reproduction and the Traffic in Images, 1841–1852. Fabrications: The Journal of the Society of Architectural Historians, Australia and New Zealand, 23(2), 156-181.
6. Chidtavong, L., Winckler, M., Bock, H. G., & Ellwanger-Mohr, M. (2016). Digitizing traditional Lao textile to modern weave technique. Chinese Business Review, 15(11), 547-555.
7. Clement, L. E. (2020). On Learning Models of Appearance for Robust Long-Term Visual Navigation (Doctoral dissertation, University of Toronto (Canada)).
8. Crişan, M.M., & Costea, R.A. (2016). Beliefs and Behaviours in Education and Culture: Cultural Determinants and Education. Toatedrepturileasupraprezentei ediţii aparţin Editurii Pro Universitaria
9. Csapo, J. (2012). The role and importance of cultural tourism in modern tourism industry. Strategies for tourism industry-micro and macro perspectives, 10, 201-212.
10. D'Ambrosio, U. (2016). An overview of the history of Ethnomathematics. Current and future perspectives of ethnomathematics as a program, 5-10.
11. D'Ambrosio, U., & Rosa, M. (2017). Ethnomathematics and its pedagogical action in mathematics education. In Ethnomathematics and its diverse approaches for mathematics education (pp. 285-305). Springer, Cham.
12. Deal, T. E., & Peterson, K. D. (2016). Shaping school culture. John Wiley & Sons.
13. Fatta, F., & Mediati, D. (2020). Geometric References of Roman Mosaics in North Africa. Nexus Network Journal, 22(1), 91-111.
14. Gong, X., Chen, X., & Zhou, Y. (2018). Advanced weaving technologies for high-performance fabrics. In High-Performance Apparel (pp. 75-112). Woodhead Publishing.
15. Jocson, E. U. (2018). Cultural Preservation and Inclusion for the Ifugao People. Journal of Southeast Asian Human Rights, 2(2), 421-447.
16. Lipps, J. (2021). Ceiling Decor Contextualised: A Case Study from the 'Casa di Augusto'on the Palatine. In Principles of Decoration in the Roman World (pp. 91-106). De Gruyter.
17. March, L., & Steadman, P. (2020). The geometry of environment: an introduction to spatial organization in design. Routledge.
18. Meller, S. (2018). Silk and Cotton: Textiles from the Central Asia that was. Abrams.

19. Messina, B., & Chiarenza, S. (2018). Geometric Links Between 2d Patterns and 3d Structures in Islamic Architectures of Andalusia. In International Conference on Geometry and Graphics (pp. 884-895). Springer, Cham.
20. Minsky, M., & Papert, S. A. (2017). Perceptrons: An introduction to computational geometry. MIT press.
21. Montgomery, F. M. (2007). Textiles in America, 1650-1870: A Dictionary Based on Original Documents, Prints and Paintings, Commercial Records, American Merchant's Papers, Shopkeepers' Advertisements, and Pattern Books with Original Swatches of Cloth. WW Norton & Company.
22. Morier-Genoud, S., Ovsienko, V., & Tabachnikov, S. (2012). 2-frieze patterns and the cluster structure of the space of polygons. In Annales de l'Institut Fourier (Vol. 62, No. 3, pp. 937-987).
23. Murphy, J., Chang, J. M., & Suaray, K. (2016). Student performance and attitudes in a collaborative and flipped linear algebra course. International Journal of Mathematical Education in Science and Technology, 47(5), 653-673.
24. Rahi, S. (2017). Research design and methods: A systematic review of research paradigms, sampling issues and instruments development. International Journal of Economics & Management Sciences, 6(2), 1-5.
25. Rosa, M., & Gavarrete, M. E. (2017). An ethnomathematics overview: an introduction. In Ethnomathematics and its Diverse Approaches for Mathematics Education (pp. 3-19). Springer, Cham.
26. Rosa, M., & Orey, D. (2011). Ethnomathematics: the cultural aspects of mathematics. Revista Latinoamericana de Etnomatemática: Perspectivas Socioculturales de La Educación Matemática, 4(2), 32-54.
**27.** Rosa, M., & Orey, D. C. (2015). A trivium curriculum for mathematics based on literacy, matheracy, and technoracy: an ethnomathematics perspective. ZDM, 47(4), 587-598.
28. Rosa, M., & Orey, D. C. (2016). State of the art in Ethnomathematics. In Current and future perspectives of ethnomathematics as a program (pp. 11-37). Springer, Cham.
29. Rosa, M., & Orey, D. C. (2020). Discussing culturally relevant education and its connection to cultural aspects of mathematics through ethnomathematics. Revista Eletrônica de Educação Matemática, 15(1), 1-20.
30. Rosa, M., D'Ambrosio, U., Orey, D. C., Shirley, L., Alangui, W. V., Palhares, P., & Gavarrete, M. E. (2016). Current and future perspectives of ethnomathematics as a program (p. 45). Springer Nature.
31. Rosa, M., Shirly, L., Gavarrete, M.E., & Alangui, W. (2017). Ethnomathematics and its diverse approaches for mathematics education. USA: Springer International Publishing.
32. Rubio, J. S. (2016). The Ethnomathematics of the Kabihug Tribe in Jose Panganiban, Camarines Norte, Philippines. Malaysian journal of mathematical sciences, 10, 211-231.
33. Septianawati, T., & Puspita, E. (2017). Ethnomathematics study: uncovering units of length, area, and volume in Kampung Naga Society. In Journal of Physics: Conference Series (Vol. 812, No. 1, p. 012021). IOP Publishing.
34. Snodgrass, M. E. (2015). World clothing and fashion: An encyclopedia of history, culture, and social influence. Routledge.

35. Vaganova, O. I., Odarich, I. N., Popkova, A. A., Smirnova, Z. V., & Lebedeva, A. A. (2019). Independent work of students in professional educational institutions. Amazonia Investiga, 8(22), 295-304.
36. Venkataraman, G. (2016). Through the symmetry lens. At Right Angles, 5(2), 11-16.

## IX. Acknowledgement

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