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GEOMETRY AND ALGEBRA IN TRADITIONAL SABU EI LEDO IKAT WEAVING MOTIFS

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Abstrak. Penelitian ini mengkaji struktur geometri dan aljabar yang terkandung dalam kain tenun tradisional Ei Ledo milik klan Hubi Iki di Pulau Sabu, Nusa Tenggara Timur, melalui perspektif Ethnomathematics. Kajian mengenai tenun tradisional selama ini umumnya lebih berfokus pada aspek simbolik budaya dan nilai estetika, sementara analisis terhadap rasionalitas matematis dan struktur komputasional yang mendasari praktik menenun masih relatif terbatas. Penelitian ini menggunakan pendekatan etnografi kualitatif yang dipadukan dengan analisis geometri, pemodelan aljabar, dan interpretasi grup simetri untuk mengidentifikasi pola-pola matematis pada motif dan proses produksi tenun. Hasil penelitian menunjukkan adanya penerapan algoritma tradisional "Mane" dengan rasio presisi satu kaki terhadap empat urat benang dengan total 144 urat benang, serta penggunaan logika Boolean dalam proses pewarnaan. Secara matematis, motif zig-zag dimodelkan sebagai fungsi periodik linear yang menyerupai gelombang segitiga, sedangkan motif lengkung "Hebe" menunjukkan karakteristik kurva polinomial berderajat tinggi. Selain itu, analisis struktur aljabar memperlihatkan bahwa motif mikro mengikuti grup simetri C2v yang menghasilkan efisiensi kognitif penenun sebesar sekitar 75% dalam proses produksi. Temuan ini membuktikan adanya penalaran matematis tingkat tinggi, komputasi mental iteratif, dan optimasi spasial dalam praktik tenun tradisional masyarakat Sabu meskipun tanpa penggunaan alat ukur modern. Penelitian ini berkontribusi terhadap pengembangan teori etnomatematika, pembelajaran matematika berbasis budaya, serta pendekatan interdisipliner yang menghubungkan pengetahuan lokal dengan pemodelan matematika kontemporer.

Kata Kunci: Etnomatematika; Tenun Ei Ledo; Grup Simetri; Logika Boolean; Pemodelan Matematis; Fungsi Periodik; Matematika Indigenous.

Abstract. This study investigates the geometric and algebraic structures embedded in the traditional Ei Ledo woven textiles of the Hubi Iki clan from Sabu Island, East Nusa Tenggara, Indonesia, through an Ethnomathematics perspective. While previous studies on traditional weaving have primarily emphasized cultural symbolism and artistic values, limited research has examined the underlying mathematical rationality and computational structures involved in indigenous weaving practices. This research employs a qualitative ethnographic approach combined with geometric analysis, algebraic modeling, and symmetry-group interpretation to identify mathematical patterns within the weaving motifs and production processes. The findings reveal the implementation of the traditional "Mane" algorithm using a precision ratio of one foot measurement to four thread units, totaling 144 thread lines, alongside the application of Boolean logic in the dyeing process. Mathematically, the zig-zag motifs were modeled as linear periodic functions resembling triangular waveforms, whereas the curved "Hebe" motifs exhibited characteristics of higher-degree polynomial curves. Furthermore, algebraic structural analysis demonstrated that the micro motifs conform to the C2v symmetry group, generating approximately 75% cognitive efficiency in the weaving process. These findings demonstrate the existence of advanced mathematical reasoning, iterative mental computation, and spatial optimization within traditional Sabu weaving practices despite the absence of modern measuring instruments. The study contributes to the development of ethnomathematical theory, culturally responsive mathematics education, and interdisciplinary approaches connecting indigenous knowledge systems with contemporary mathematical modeling.

Keywords: ethnomathematics; Ei Ledo weaving; symmetry groups; Boolean logic; mathematical modeling; periodic functions; indigenous mathematics.

A. Introduction

Mathematics is frequently perceived as a formal and abstract discipline detached from everyday cultural practices. However, numerous studies in Ethnomathematics demonstrate that mathematical ideas have long been embedded within traditional knowledge systems, artistic expressions, and indigenous technologies. D'Ambrosio (1985) introduced ethnomathematics as a conceptual framework that examines mathematical practices developed and utilized by specific cultural groups in order to understand, organize, and interact with their environment. Within this perspective, mathematical reasoning is not limited to formal academic institutions, but also emerges through local wisdom, craftsmanship, and collective cultural experiences.

Traditional textile production represents one of the most significant manifestations of ethnomathematical practice. Gerdes (1999) emphasized that weaving traditions in many indigenous societies contain implicit mathematical structures, including symmetry, geometric transformations, proportional reasoning, and algorithmic repetition. Similarly, Washburn and Crowe (1988) argued that textile motifs and ornamental patterns can be systematically analyzed using plane symmetry groups and geometric pattern analysis. Studies on cultural symmetry by Weyl (1952) and Armstrong (1988) further demonstrate that repetitive visual structures in traditional art frequently correspond to formal algebraic systems and group-theoretical principles.

In the Indonesian context, traditional woven textiles constitute an important repository of indigenous mathematical knowledge. The diversity of motifs, spatial arrangements, and repetitive structures found in Indonesian weaving traditions reveal sophisticated forms of geometric organization and symbolic representation (Gittinger, 1979; Maxwell, 1990). Among these traditions, the ikat weaving culture of Sabu Island in East Nusa Tenggara possesses distinctive visual characteristics and cultural meanings. For the Sabu (Sawu) community, woven textiles function not merely as clothing, but also as cultural symbols associated with social identity, ritual ceremonies, kinship structures, and cosmological beliefs. Although the social functions of woven textiles have evolved over time, their essential symbolic and cultural significance remains preserved (Talo, 2004).

One important traditional textile from this region is *Ei Ledo*, a women's sarong associated with the Hubi Iki clan, commonly referred to as "Bunga Kecil." According to Ammu Hawu (n.d.), the Hubi Iki motifs are characterized by relatively small and repetitive visual structures symbolizing modesty, simplicity, and humility, in contrast to the larger motifs associated with the Hubi Ae clan. The collections documented by the Museum Negeri Propinsi NTT (n.d.) further indicate that each motif arrangement reflects particular clan identities and social classifications within Sabu society.

Despite increasing scholarly attention toward ethnomathematics and traditional textiles, previous studies have predominantly focused on cultural symbolism, anthropological interpretation, and aesthetic values, while limited research has systematically investigated the underlying mathematical structures embedded within weaving practices. In particular, there remains a significant research gap concerning the integration of geometric modeling, algebraic structures, symmetry analysis, and computational reasoning in the study of Sabu ikat motifs. Existing studies rarely examine how traditional weavers employ iterative counting systems, spatial algorithms, proportional logic, and visual symmetries in the production process despite the absence of modern measuring instruments.

Therefore, this study aims to analyze the geometric and algebraic structures embedded in the *Ei Ledo* weaving motifs of the Hubi Iki clan through an ethnomathematical approach. The research specifically investigates the mathematical logic underlying thread-binding algorithms, motif repetition patterns, periodic structures, and visual symmetries. By integrating concepts from geometry, algebra, symmetry groups, and mathematical modeling, this study seeks to demonstrate that traditional Sabu weaving practices embody sophisticated forms of indigenous mathematical reasoning and computational thinking. Furthermore, the findings are expected to contribute to the development of culturally responsive mathematics education, the preservation of indigenous knowledge systems, and interdisciplinary studies connecting mathematics, culture, and traditional art

B. Methodology

This study employed a qualitative exploratory design grounded in Ethnomathematics to investigate the geometric and algebraic structures embedded in *Ei Ledo* woven textiles from the Hubi Iki clan of Sabu Island, Indonesia. The methodological framework integrated ethnographic documentation, computational geometry, numerical modeling, and group-theoretical analysis to formalize indigenous mathematical practices within traditional weaving systems.

a. Digital Documentation and Virtual Participatory Observation

Primary data were collected through virtual participatory observation and semi-structured interviews with an indigenous weaver, Mama Nabula Migu. Due to geographical constraints, data acquisition was conducted through synchronous and asynchronous digital communication platforms. High-resolution visual documentation of the *mane* thread-binding process and *Ei Ledo* motifs was systematically recorded to preserve structural fidelity for subsequent mathematical analysis. This approach follows ethnomathematical methodologies emphasizing cultural practice as a source of mathematical knowledge (D'Ambrosio, 1985; Gerdes, 1999).

b. Geometric Coordinate Extraction Using GeoGebra

Documented motif images were imported into GeoGebra Classic 6 for geometric digitization within a Cartesian coordinate framework. Coordinate points (x_i, y_i)were plotted along zig-zag vertices and *Hebe* curve structures to generate discrete spatial datasets representing thread trajectories and motif periodicity. Precision calibration and high-magnification plotting were applied to minimize positional estimation errors. This procedure enabled the identification of geometric transformations and symmetry structures consistent with plane pattern analysis methodologies (Washburn & Crowe, 1988).

c. Computational Modeling and Curve Fitting

The extracted coordinate datasets were analyzed using Python 3.11 with NumPy and SciPy libraries. Numerical optimization and least-squares curve fitting techniques were employed to construct continuous mathematical representations of the motif structures.

d. The zig-zag motifs were modeled as periodic triangular wave functions

Meanwhile, the curved *Hebe* motifs were approximated using high-degree parametric polynomial functions $X(t)$and $Y(t)$, producing an eighth-degree polynomial curve that mathematically characterizes the motif morphology. The modeling approach was informed by computational approximation theory and advanced mathematical modeling frameworks (Kreyszig, 2011; Zill, 2018). To ensure methodological reproducibility, all computational scripts and Jupyter notebooks were archived in a public GitHub repository.

e. Algebraic Structure Analysis through Group Theory

The final stage involved algebraic formalization of motif symmetries using group-theoretical analysis. Based on the geometric transformations identified in GeoGebra, invariant operations under reflection and rotation were examined to determine correspondence with the C_{2v}point symmetry group. A fundamental domain of the motif was isolated and subjected to rotational and reflective transformations to evaluate structural invariance and compositional efficiency. This analytical framework draws upon abstract algebra and symmetry theory (Gallian, 2016; Armstrong, 1988; Weyl, 1952), enabling the interpretation of traditional

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weaving patterns as mathematically optimized systems exhibiting recursive symmetry and spatial efficiency.

C. Results and Discussion

a. Cultural Identity and the Philosophy of the Womb

The textile analyzed in this study is *Ei Ledo*, a traditional women's woven cloth of the Hubi Iki clan from Sabu Island. Visually, the textile is characterized by a dark (*ledo*) background combined with relatively small repetitive ornaments. The philosophical foundation of the motif derives from the concept of the womb, symbolizing fertility, continuity of life, and femininity within Sabu cosmology. This interpretation is consistent with the traditional classification of Sabu weaving motifs distinguishing the identities of Hubi Ae and Hubi Iki clans (Ammu Hawu, n.d.).

Unlike the larger and more dominant motifs associated with Hubi Ae, the Hubi Iki motifs exhibit smaller geometric structures that reflect modesty and humility. Geometrically, the motifs do not exclusively employ rigid linear constructions; instead, they integrate organic curves and smooth spatial transitions representing *lane*, or empty spatial regions associated with simplicity and restraint.

Figure 1. Ei Ledo Textile Motif

b. Rationalization of the Mane Algorithm and Binary Logic

Prior to the visual emergence of the motif, the weaving process involves a mental computational system locally known as the *Mane* algorithm. Rather than sketching motifs directly onto the textile surface, the weavers construct patterns through precise numerical calculations performed on bundles of undyed threads. The system applies a local unit conversion in which one foot (*kaki*) corresponds to four thread strands.

For example, the production of a standard *Ei Ledo* textile requires a width of 36 feet, equivalent to 144 thread strands manually calculated and organized by the weaver. This procedure demonstrates the existence of an indigenous numerical algorithm functioning as a spatial encoding mechanism within the weaving process.

Beyond numerical counting, the thread-binding procedure also reveals an implicit application of Boolean binary logic in color distribution. In this system, the state "1" represents tied threads that resist dye absorption and preserve the original white color, whereas the state "0" represents untied threads that absorb pigments and subsequently become red or black. This binary operational structure closely resembles computational logic systems in modern information theory.

The findings indicate that traditional Sabu weavers employ systematic forms of iterative computation and binary decision-making despite the absence of formal mathematical notation or technological instruments.

c. Visual Geometric Structures of the Ei Ledo Motif

Geometric analysis of the textile patterns revealed several embedded mathematical concepts within the *Ei Ledo* motifs. First, linear structures within the textile represent parallel lines and arithmetic repetition sequences that regulate the spatial rhythm of the weaving arrangement. Second, chain and rhombic motifs demonstrate congruence relations and tessellation principles through repeated geometric units covering the textile plane without overlap. Third, the zig-zag structures exhibit angular repetition and geometric transformation patterns, particularly translational symmetry along the horizontal axis.

These geometric characteristics indicate that the motif construction process follows implicit spatial rules and proportional consistency maintained through repetitive manual operations.

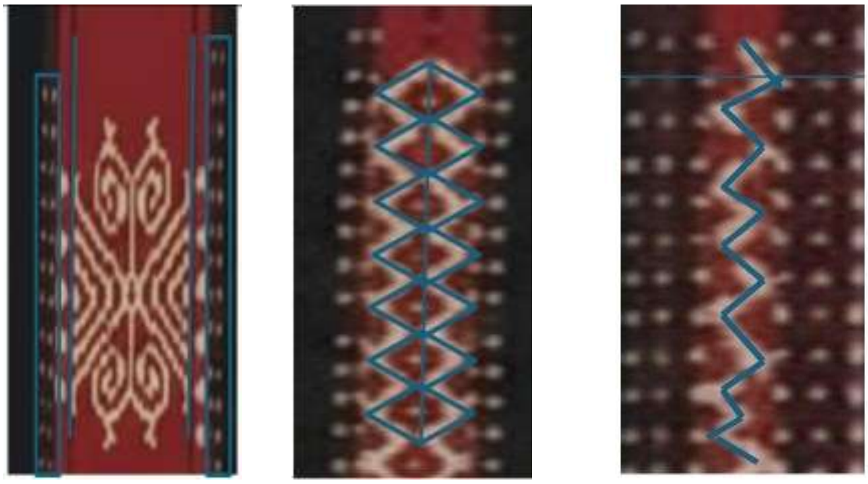

Figure 2. Geometric Components of the Ei Ledo Motif

d. Periodic Function Modeling of the Zig-zag Motif

Computational analysis further demonstrated that the zig-zag motif is not merely a collection of arbitrary broken lines, but rather a highly structured piecewise linear periodic function closely approximating a triangular waveform. Using coordinate extraction and numerical optimization, the motif was modeled by the following inverse trigonometric periodic function:

$$y = 0.17\left(\frac{2\sin^{-1}(\sin(8.61x + 1.50))}{\pi}\right) + 0.239$$

The resulting model reveals several significant mathematical properties.

First, the amplitude $(A = 0.17)$ reflects the consistency of vertical thread tension maintained by the weaver throughout repetitive weaving cycles. Second, the estimated period

$$T = \frac{2\pi}{8.61} \approx 0.73$$

indicates a highly stable horizontal repetition interval within the motif structure. This finding suggests that the weavers possess a remarkably precise spatial rhythm capable of maintaining proportional consistency without measurable distortion across the textile plane. Furthermore, the existence of a single continuous mathematical representation confirms the application of translational geometric transformations through iterative mental computation. The weavers repeatedly reproduce peak and trough positions using internalized spatial memory rather than external measuring devices.

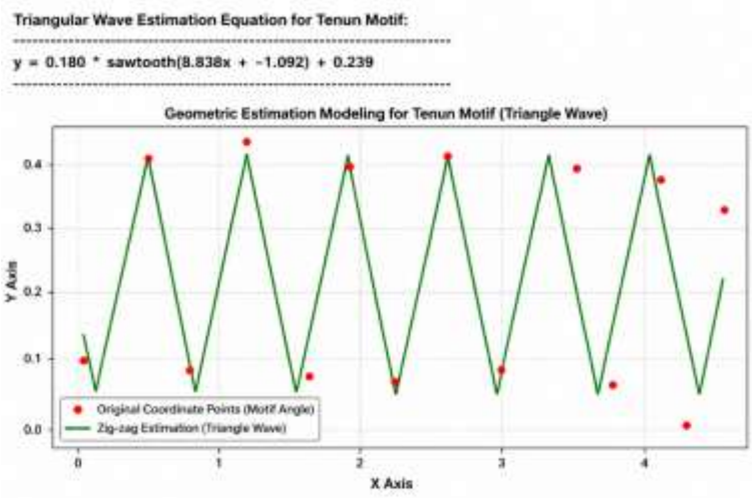

Figure 4. Triangular Wave Modeling of the Zig-zag Motif

e. The Hebe Curve and Higher-Degree Polynomial Structures

One of the most significant findings emerged from the analysis of the curved *Hebe* motif. Visually, the motif appears to resemble a simple semicircular form. However, computational modeling revealed that the curve is more accurately represented as a higher-degree polynomial structure, specifically an eighth-degree parametric polynomial. The resulting curve demonstrates continuous smoothness and gradual curvature transitions that cannot be adequately approximated using elementary geometric forms. Despite the absence of computational tools, the weavers successfully maintain curve continuity through intuitive thread-binding techniques and embodied spatial perception.

Mathematically, the Hebe motif represents an advanced form of indigenous geometric cognition in which complex polynomial-like structures emerge from traditional artistic practices. Symbolically, the smooth curvature visually represents the philosophy of the womb and feminine fertility central to Sabu cosmology.

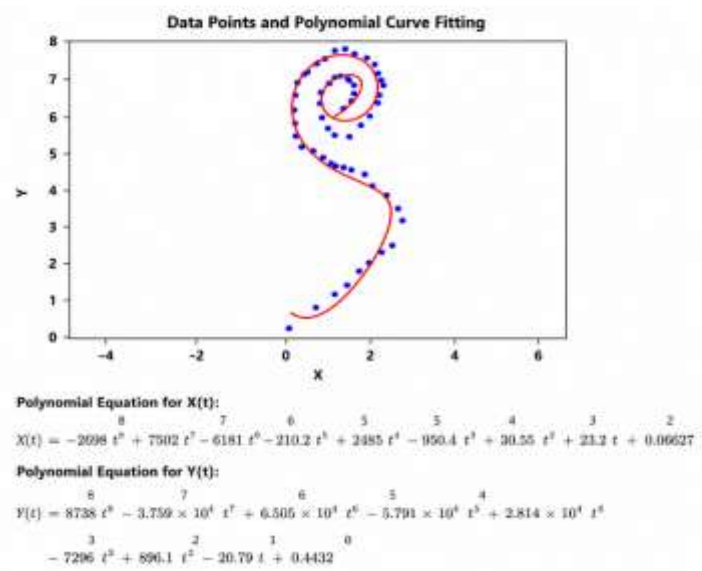

Figure 5. Higher-Degree Polynomial Representation of the Hebe Curve

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f. Algebraic Structure and the C_{2v}Symmetry Group

At the microstructural level, the *Ei Ledo* motif satisfies several axioms of abstract algebra, particularly those associated with symmetry group theory. Geometric analysis demonstrated that the motif conforms to the C_{2v}point symmetry group (2mm notation), characterized by two reflection symmetries and one rotational symmetry.

Specifically, the motif exhibits:

1. invariance under vertical reflection (σ_v),
2. invariance under horizontal reflection (σ_h), and
3. rotational invariance under 180°rotation (C_2).

Figure 6. C_{2v}Symmetry Structure of the Ei Ledo Motif

An important implication of this structure is the emergence of cognitive efficiency in the weaving process. The weavers only need to construct a single fundamental domain corresponding to approximately one-quarter of the motif structure. The remaining portions are generated mentally through reflection and rotational transformations. This demonstrates the existence of recursive spatial reasoning and symmetry-based optimization within traditional weaving cognition.

Interestingly, a mathematical paradox emerges within the textile composition. At the microstructural level, the motifs exhibit strict algebraic symmetry governed by the C_{2v}group. However, at the macrostructural level of the full textile arrangement, the weavers intentionally introduce asymmetry to create visual dynamism and artistic variation. This phenomenon reflects a sophisticated balance between formal mathematical order and aesthetic freedom in indigenous textile design traditions.

The findings reveal that traditional Sabu Ei Ledo ikat weaving motifs embody various geometric and algebraic concepts, reflected in patterns of symmetry, transformation, and repetition. These results support previous studies indicating that the integration of local wisdom into mathematics learning can strengthen students' mathematical reasoning and communication skills (Ashari, 2025). Therefore, the use of Sabu Ei Ledo weaving motifs as an ethnomathematical learning context has the potential to create more meaningful learning experiences by connecting formal mathematical concepts with local cultural practices that are familiar to students.

D. Conclusion

This study demonstrates that the *Ei Ledo* woven textile of the Hubi Iki clan embodies a highly sophisticated form of indigenous mathematical cognition integrating numerical algorithms, binary logic, geometric precision, and algebraic symmetry within traditional weaving practices. The findings reveal that the weaving process is governed by a systematic

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computational structure, including the calculation of 144 thread strands through the *Mane* algorithm, the application of Boolean-based dyeing logic, and the construction of geometric motifs modeled as periodic triangular wave functions and higher-degree polynomial curves.

Furthermore, the identification of the C_{2v}symmetry group confirms that the microstructural composition of the motifs follows formal principles of transformational geometry and abstract algebra. The use of rotational and reflective operations derived from a single fundamental domain indicates the presence of advanced cognitive efficiency and recursive spatial reasoning among traditional Sabu weavers, despite the absence of modern measuring instruments or formal mathematical notation.

These findings challenge the conventional assumption that advanced mathematical reasoning is exclusively associated with formal scientific institutions. Instead, the study demonstrates that indigenous cultural practices preserve complex systems of mathematical knowledge embedded within artistic production and collective memory. From an academic perspective, this research contributes to the advancement of Ethnomathematics by bridging indigenous knowledge systems with computational modeling, geometry, and algebraic theory.

Future research should extend comparative analyses to other Sabu weaving traditions, particularly the Hubi Ae clan motifs, in order to investigate broader variations in mathematical structure and symbolic representation. Additionally, the findings provide a strong foundation for the development of culturally responsive mathematics curricula that integrate local wisdom into contemporary numeracy and mathematical literacy education.

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