Ethnomathematics Exploration of the Toba Community: Elements of Geometry Transformation Contained in Gorga (Ornament on Bataks House)

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Abstract. Gorga is an ornament known to the Batak community. As one of the works of art that poured in the form of carvings, gorga become icons for batak society. Long before the Batak people knew formal education, they had made gorga. This is evidenced through several historical sources. Gorga not only contains the value of art but also has a mathematical element. There are many mathematical principles used in the process of making gorga. The principle of geometry transformation is very prominent in the gorga motifs. This article is an ethnomathematics research that will discuss how the thinking process in making gorga. Observations and interviews with the gorga craftsmen (pande) are conducted to find out how the principles of rotation, translation, dilation and reflection are used in making gorga motifs

1. Introduction

The word ornament comes from the Latin ornare, which has the meaning of adorning. According to [1] ornaments "are components of art products that are added or deliberately made for the purpose of decoration. So, based on that understanding, ornament is the application of decoration on a product. The ornamentalmain function is to beautify the objects of products or items decorated".The presence of an ornament is not merely as a filler of the empty and meaningless, like the works of the past ornaments. The various forms of ornaments actually have functions, namely (1) purely aesthetic functions, (2) symbolic functions, (3) constructive engineering functions.

A purely aesthetic function is an ornamental function to embellish the appearance of a decorated product form to become a work of art. The function of such ornaments is evident in the products of ceramics, batik, weaving, woven, jewelry, traditional weapons, household appliances, and leather and wooden crafts that emphasize the aesthetic value of the ornaments it implements.

The symbolic function of ornaments is commonly found in ceremonial or biblical objects of religion and belief, accompanying the aesthetic value. For example ornaments that use motif kala, monitor lizards, dragons, birds or *garuda*, the works of the past function symbolically. In its later development, the symbolic aspect of an ornament increasingly loses its meaning.Toba or Gorga Batak traditional ornaments are all kinds of ornaments made to beautify the traditional house (exterior of the house), which is passed down from generation to generation based on the mindset of Batak Toba society. Gorga scattered throughout the Toba region and not always evenly sub-sub Toba region. Toba Batak society in particular at this time, less or even not understand with things about the culture. One of them is the understanding of *Gorga*.

Gorga Batak is one of Batak art and culture that is old enough. A traditional sculpture made naturally. In ancient times, *gorga* was only made for a house that is considered honorable, because Batak Ancestors consider that gorga is not just an ornament, but has a meaning that reflects the life of the Batak. Usually *gorga* found on the walls of traditional houses Batak tribe. The only traditional Batak traditional house in Samosir is located in Parmonangan Village, Simanindo District. Batak house, built 350 years ago. The house belongs to *Opung Souaon Situmorang*. The house still looks complete with *gorga* or original Batak carvings.

Other mathematical concepts that we can observe one of them is the Batak ornament (gorga). As we know from the above explanation that gorga far already found before the Batak people learn geometry. The motives found in gorga use the concept of transformation geometry such as reflection, shifting, rotation, and rescaling. All science including mathematics is a product produced from a culture or human civilization. The process of creating meaning through a culture-based learning process has several components, meaningful tasks, active interaction, explanation and application of the science contextually, and the use of diverse learning resources [2][3]. In cultural-based learning, culture becomes a method for students to transform their observations into creative forms and principles about the field of science. One form of cultural-based learning is ethnomatematics (Ethnomathematics).

D'Ambrosio [4] says Ethnomatematics is the study of mathematics which takes into account cultural considerations in which mathematics arises by understanding the reasoning and mathematical systems they use. The study of ethnomatics in mathematics learning encompasses all areas: architecture, weaving, sewing, agriculture, kinship, ornament, and spiritual and religious practices often in harmony with patterns occurring in nature or ordering systems of abstract ideas. According to [5], ethnomatics includes mathematical ideas, thoughts and practices developed by all cultures. Etnomathematiics can also be considered as a program that aims to study how students to understand, articulate, process, and ultimately use math ideas, concepts, and practices that can solve problems related to their daily activities.

Ethnomatics recognizes that there are different ways of doing mathematics by considering the acquisition of mathematical academic knowledge developed by different sectors of society and taking into account the different modes in which different cultures negotiate about their mathematical practice [6-8]. The purpose of studying etnomatology is to understand the interrelation between mathematics and culture, so that students and society's perception of mathematics becomes more appropriate, and mathematics learning can be better adapted to the cultural context of students and society, and mathematics can be more easily understood because it is no longer perceived as foreign by students and society. Another goal is to optimize the application and the benefits of mathematics for the life of students and the wider community more, so that students and society obtain the optimal benefits of mathematics learning activities.

2. Method

The type of this research is qualitative research. Place of study is Toba Samosir District. Methods of data collection using interviews recorded and direct observation. Subjects to be interviewed are customary figures and some *gorga* craftsmen. Interview data will be made in the form of transcripts of the conversation, while the observed data is documented in the form of photographs. Interview transcripts along with photographs will be analyzed and elaborated to explain the concept of transformation found in gorga.

3. Result and Discussion

The transformation of geometry is to change each point coordinate (the points of a wake) into other coordinates on a plane with one particular rule. For example, the transformation (T) to point P (x, y) produces a shadow P '(x', y '), the operation can be expressed as follows:

$$P(x, y) \rightarrow P'(x', y')$$

Some gorga motifs show that there are several transformation principles used such as:

3.1. Translations

Translation is a transformation that moves each point on a plane by a certain distance and direction. The distance and direction of a translation can be represented by a directed line segment, eg $\overrightarrow{AB}$ or a pair of numbers $\binom{a}{b}$, where "a" represents the distance and direction of movement horizontally (horizontally) and "b" represents the distance and direction of displacement vertically (upright). At one translation each wake does not change. The translation operation can be expressed as follows:

$$A(x,y) \xrightarrow{T=\binom{a}{b}} A'(x',y') = A'(x+a, y+b)$$

Gorga motif similar to parang batik motif is also formed from the translation of one object. Figure 1 shows the translational process along the horizontal line to form new objects such as the repetition of the previous object. The direction and shape is also exactly the same as the previous form.

Figure 1. Translation in Gorga Motifs

3.2. Reflection

Reflection is a transformation that moves each point on a plane by using the mirror image of the points to be moved. For reflection of the y-axis (vertical), if the point shadow P (x, y) is P '(x', y ') then P' (x ', y') = P '(- x, y), the matrix form can be written as follows:

$$x' = -x$$

$$y' = y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

The following figure is an example of a reflection on the vertical axis of the gorga motif:

(i)

(ii)
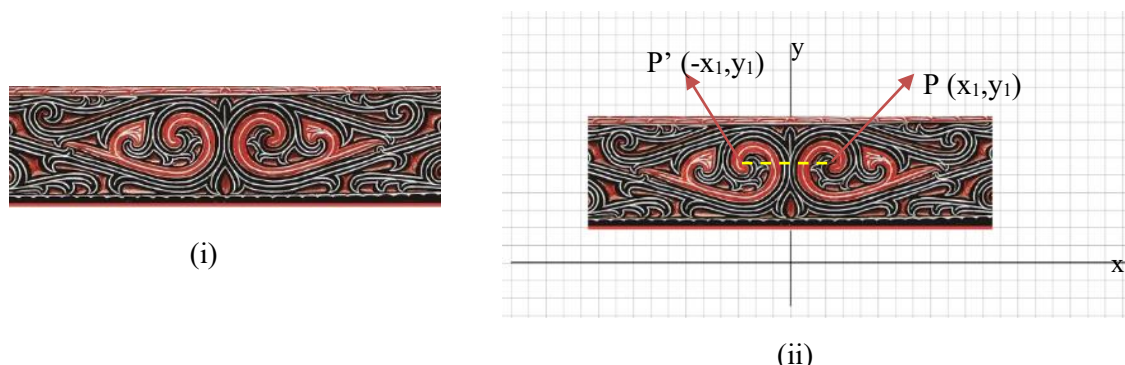
Figure 2. Gorga motif is reflected on the axis "y" (vertical)

Figure 2 (i) shows one of the gorga motifs reflected on the vertical axis. In Figure 2 (ii) it is seen that the coordinates of point P (x, y) after being reflected then the shadow coordinates of point P or so called P 'are (-x, y). From the figure we can observe that the distance of point P to the y-axis is equal to the distance of point P 'to the y-axis. It satisfies the properties of reflection: (1) In the reflection of

an object and its image will be congruent, but there is an inverted orientation; (2) Any point located on the axis of the reflection is not invariant; (3) The distance of each point on the object to the reflection axis is equal to the distance of each shadow point to the reflection axis; (4) The angle formed by the reflection axis with the line connecting each point to its shadow is right-angled.

For reflection of the x axis (horizontally), if the point shadow P (x, y) is P '(x', y ') then P' (x ', y') = P '(x, -y) the matrix can be written as follows:

$$x' = x$$

$$y' = -y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

So $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$, is the reflection matrix of the y axis.

3.3. Rotation

Rotation is a transformation that moves a point on a plane of another point by rotating to a particular center point. In rotation or rotation on a plane is determined by the center of rotation. Rotation center point is a fixed point or a center point used as a reference to determine the direction and magnitude of the rotation angle. On a rotation, each wake does not change its shape. The direction of rotation is agreed with the following rules: (1) If the rotation is opposite to the clockwise direction, then the rotation is positive (+). (2) If rotation is clockwise, then this rotation is negative (-). (3) The magnitude of the rotational angle determines the rotation. Deep rotation is expressed in the fractional plane against a full rotation (360º) or large angle in degrees or radians.
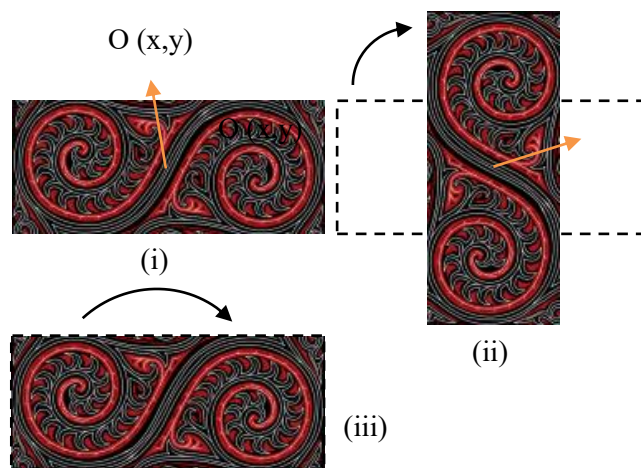

Figure 3. Rotation of *Gorga* Motif With Center Point O (x, y)

In Figure 3 one of the *gorga* motifs is rotated clockwise at $180^{\,o}$ with the center point O (x, y). It turns out that the rotation does not change the shape of the motive. The interesting thing about the gorga motif is that if rotated as far as $180^{\,o}$ with the position of the center point O (x, y) as in the picture of 6 parts (ii), then the motive seems to have no rotation, because the motive is the same as before rotation .

3.4. Dilatation

Dilatation is a transformation that changes the size or scale of a geometry build whether it magnifies or wakes up but does not change the shape of the wake. A dilatation on the plane is determined by the center of dilation and dilation factor (scale factor). Notice the dilation of some objects in the Figure 4

(i)   (ii)
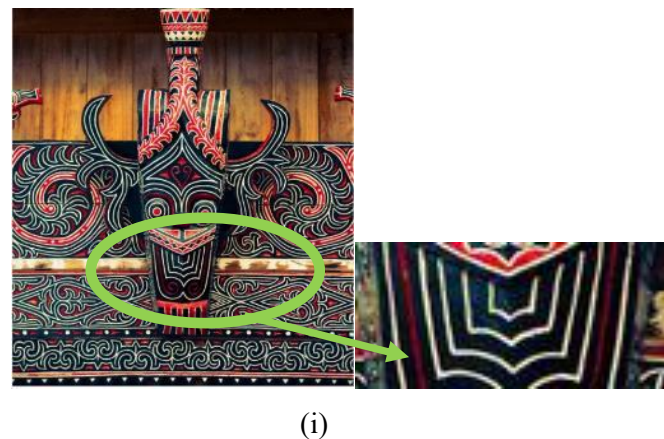
Figure 4. Dilatation on *Gorga* motif "Ulu Paung"

Figure 4 shows that there is a positive dilation process or magnification on the *Gorga* motif. In the process of dilatation, the result object is dilated similar to the original object. In the 6-part (ii) if it is enlarged, it appears that the shape of the dilated object is not very precise. This may happen because some factors like the process of shooting / photos are not right in the middle of the object so that change the point of view, other factors are the process of *ulu paung* is not like other *gorga* motif generally made on the plane board, while the field surface which is found in the *ulu paung* motif is curved.

4. Conclusion
Batak society has known the geometry of transformation for a long time ago. It can be seen from the principles of the transformation geometry that they use in the making of a work ornament called Gorga. From some *gorga* motifs can be concluded that the motive has been using the principle of reflection, rotation, translation and dilatation. Gorga made using traditional tools so that in some motives found not too precise. It is interesting to see that the accuracy of their calculations by using simple tools of their day requires a mathematical ability that is good enough for the craftsman in making a motif *gorga*. For further research it is possible to observe Gorga in terms of mathematical abilities used.

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