Form Finding Architectural Shading Device: Reinterpretation of Batik Pattern through Parametric Approach

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Abstract. The use of technology is a big opportunity to explore architectural design. This research examines the possibility of form-finding process by using computational design approach to generate shading devices that can represent local identity and provide efficient energy use of the building. Some examples of geometric Batik patterns found on the local screen used in one of the Indonesian traditional houses will be transformed into perforated shading devices. The process consists of three stages: understanding the symmetry group of each pattern with crystallographic chart analysis, generating a digital mesh of the objects by using photogrammetry method, and reinterpreting the object mesh to the perforated panel using parametric approach. The result shows that Banji pattern on $p4gm$ symmetry group, while Kawung pattern on $p4mm$, Parang pattern on $p1$, and Nitik pattern on $c2mm$. On the photogrammetric stage, the digital three-dimensional meshes are successfully formed by using 13-19 overlapping photographs of the objects. From the last stage, perforated batik pattern panels are generated and it is possible to set the perforation percentage to reach desired WWR value. This experiment indicates that the use of computational design is possible to develop the local ornaments into a controllable perforated shading device.

1. Introduction

The increased use of technology and computational design approach in architecture allows architects to explore the design and modeling techniques. These methods are extending the range of possibilities to architecture on several important design considerations such as culture and environmental issues.

1.1. The Use of Technology to Preserve Local Ornament in Architecture

One of the designs that indicate the use of technology to produce a re-interpretation of the traditional patterns as shading is residential buildings of Masdar Institute (2010) by Foster and Partners (Fig. 1). A contemporary transformation of mashrabiya, a type of traditional latticed shading device becomes the effective protection for the windows to reduce the cooling loads. The use of modern mashrabiya also found in Institut du Monde Arabe (1987) in Paris by Jean Nouvel (Fig. 2). This design also characterizes the local identity and provides sun-shading for cooling. The architect, Jean Nouvel has even develop mashrabiya pattern and transform it into high tech solar screens to cover the whole building of Doha Tower (2012) (Fig. 3). The multi-layered aluminum elements have various perforation percentages to respond the solar radiation depends on each surface orientation.
Traditional screens with local ornaments also found in some traditional houses in Indonesia. The pattern of the ornaments can be varied, and some of them are identical to the Batik pattern (Fig. 4). But recently, these traditional screens are very difficult to find due to its very limited availability.

In this paper, the traditional screen patterns from Indonesia especially Batik patterns are transformed into the new configurations of shading devices by applying some of the basic mathematical rules like the symmetry of the patterns and various dimensions of the geometry. Hopefully, the new configurations can represent the local identity and provide efficient energy consumption of the building and better daylight performance.

1.2. Batik Pattern
Javanese Batik becomes a part of the national identity and a national icon of Indonesia [2]. Based on the ornaments and their structures, classical batik can be divided into geometric and non-geometric patterns. The geometric patterns are recognizable due to the symmetry and the iterations. While non-geometric patterns are generally an irregular arrangement of plants, mountains, animals, or other creatures [3][4]. This study focused on the geometric pattern for its easy recognizable shape. Four geometric patterns: Banji, kawung, parang, and nitik will be developed to generate the architectural element design. According to Moertini [3], Haake [5], and Susanto [4] the pattern of Banji is built up from interconnected swastika at the angle of 90 degrees. It is the symbol for a lucky life. Kawung pattern is a repetitive ellipse or intersecting circles that has philosophical meaning to give hope, wisdom, and guidance. Parang is a gently curved design that runs diagonally in a powerful rhythm, where additional ornaments filled the space between the diagonal main ornament. It represents changes, dynamics, and strength. While Nitik recognized by the rows of its dots and short stripes that run parallel at certain angles in a pattern that imitates woven decoration.

2. Methods
This study consist of three stages: understanding the symmetry group and the “fundamental” region of each pattern, scanning the three-dimensional shape of the object to generate a digital mesh of the patterns, and transforming the three-dimensional mesh to perforated panel.

2.1. Understanding the fundamental principles of the Patterns
According to Susanto [4], geometric batik patterns consist of repetitive geometrical decorations in a certain order of arrangement. To analyze the fundamental principles of each pattern, a crystallographic chart by Schattschneider (Fig. 6) is used. This chart classifies the symmetry groups of the pattern that shows a set of isometries which map the pattern onto itself according to their symmetry groups on the two-dimensional counterpart of the system [6].

Figure 1. Residential buildings of Masdar Institute [1]
Figure 2. Institut du Monde Arabe [1]
Figure 3. Doha Tower [1]
Figure 4. Traditional screen found in Kudus, Indonesia
2.2. Extracting the three-dimensional shape of the batik carving in digital form

The three-dimensional form of batik patterns are used as the objects that will be transformed into a planar perforated panel. The use of two-dimensional batik images is also possible to generate this perforated shading with the color attribute as the recognizable data. However, the software's ability is only limited to the black and white images, so the form recognition is relatively limited. Thus three-dimensional objects are more appropriate to be used in this study because three-dimensional form has depth attributes that can be converted to measurable data set. Four different batik pattern carvings on wood medium are prepared to process the photogrammetric stage. As mentioned before, the patterns used in this study are: Banji, Kawung, Parang, and Nitik (Fig. 7).

![Figure 5. International notation of seventeen two-dimensional crystallographic chart [6]](image)

![Figure 6. Batik pattern carving in wood medium](image)

The photogrammetry method is used to scan the three-dimensional form of each pattern. According to Romero & Bustamante [7], photogrammetry is a three-dimensional measurement technique that uses photography to get metric information of a particular object by using several photos from different sides to reconstruct the shape into a digital model. The software used in this study is Agisoft Metashape Professional (Fig. 8). Multiple overlapping photographs will be transformed into a digital three-dimensional mesh object (Fig. 9).

![Figure 7. Agisoft Metashape Interface](image)  
![Figure 8. Photogrammetry scheme [8]](image)

2.3. Transforming the three-dimensional form into perforated panel

The generated meshes of three-dimensional objects from the previous stage are translated to “brep” mesh objects in Grasshopper, a plugin for Rhinoceros software. The parametric approach is used in this stage.
According to Hernandez [9], parametric design is a process of designing where a design is constructed with geometrical entities that have fixed attributes (properties) and others can be varied. The variable attributes are also called parameters and the fixed attributes as the limitation. The numerical data of the measurable points form the three-dimensional mesh is the main parameter which generates various configuration of Batik pattern perforated panel while the perforation percentage will be the fixed properties.

3. Result
3.1. Understanding the fundamental principles of the Patterns
From the method formerly mentioned, the following table shows the result of the symmetry group analysis process:

| Table 1. Symmetry Group and arrangement of each pattern |
|-----------------------------------------------|
| **Banji Pattern** | **Kawung Pattern** |
| Symmetry: p4gm | Module | Arrangement | Symmetry: p4mm | Module | Arrangement |
| ![Symmetry p4gm](image) | ![Module](image) | ![Arrangement](image) | ![Symmetry p4mm](image) | ![Module](image) | ![Arrangement](image) |
| **Parang Pattern** | **Nitik Pattern** |
| Symmetry: p1 | Module | Arrangement | Symmetry: c2mm | Module | Arrangement |
| ![Symmetry p1](image) | ![Module](image) | ![Arrangement](image) | ![Symmetry c2mm](image) | ![Module](image) | ![Arrangement](image) |

Key:
- Center of four-fold rotation
- Axis of glide-reflection
- Translation vector
- Outline of centered cell
- Axis of reflection
- Center of two-fold rotation

*ABCD (“tubruk”): Patterns are vertically and horizontally arranged by shifting in one step.
*OPQR: Paralelogram module are diagonally arranged.
*WXYZ (tubruk miring): Patterns are diagonally arranged by shifting in one step to the right and left.

3.2. Extracting the three-dimensional shape of the batik carving in digital form
By using photogrammetry method, generated mesh objects are shown in Table 2.

| Table 2. Generated Mesh on Photogrammetry Process |
|-----------------------------------------------|
| **Banji** | **Kawung** |
| Point Cloud Stage | Dense Cloud Stage | Generated Mesh | Point Cloud Stage | Dense Cloud Stage | Generated Mesh |
| ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) |
| **Parang** | **Nitik** |
| Point Cloud Stage | Dense Cloud Stage | Generated Mesh | Point Cloud Stage | Dense Cloud Stage | Generated Mesh |
| ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) | ![Generated Mesh](image) |

3.3. Transforming the three-dimensional form to perforated panel
Step by step of form-finding process to generate perforated Batik pattern shading device are displayed in Table 3.
Table 3. Form-finding Process to Generate Batik Pattern Perforated Panel

| Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 | Stage 6 |
|---------|---------|---------|---------|---------|---------|
| Fundamental region on the imported mesh | Sub-surfaces on the projecting plane surface | Intersection points between constructed lines from mid-point of sub-surfaces to the mesh | Perforation geometries on the mid-points of each sub-surfaces | Resized perforations dimension based on the numerical data of the intersection points | Duplicated fundamental region based on the symmetry group |

4. Discussion

The shape of Banji pattern module is rectangular that its highest order of rotation of this pattern is four. It has reflections and glide reflections. The “fundamental” region is on the 1/8 unit of the module. The four-fold centers are not on the reflection axes. Thus Banji pattern characterizes p4gm symmetry group of the classification. While Kawung pattern shows the characteristic of p4mm symmetry group which has a rectangular modular shape with four highest order of rotation. Reflection and glide rotation also exist on this pattern, and the “fundamental” region lies on the 1/8 unit of the module. Parang pattern has has a parallelogram shape as the modular lattice which has no reflection and glide rotation. The “fundamental” region is on the whole unit, which means that the symmetry group of Parang pattern is p1. Nitik pattern module is a rhombic that consist of two highest order of rotation. It has perpendicular reflection axes and glide rotation, and the “fundamental” region of this pattern lies on 1/4 unit of the modular. It indicates that Nitik pattern is on c2mm symmetry group.

The Photogrammetric process in Agisoft Metashape software takes 13-19 photographs to generate a 15 cm x 20 cm x 3 cm wood carving. It means that the photographs must be taken in every 1.1 cm up to 1.2 cm to create overlapping images. Multiple overlapping photographs will be aligned to construct the point clouds, then developed to build dense clouds. The next step is to generate mesh from the prepared dense clouds. The 3D object scanning process will be done completely by saving the generated mesh in “.obj” file for the next process in Rhinoceros and Grasshopper software. Generated perforated Batik panels from parametric process in Rhinoceros and Grasshopper software can be modified into some configurations by parametrically setting the amount of the perforations and resizing each perforation’s dimensions. In the previous research, Hariyadi & Fukuda [10] concluded that to achieve a minimum OTTV value in accordance with SNI standards required 22.05% Window to Wall Ratio (WWR) with clear glass (SHGC 0.7) openings. This consideration will be fixed attributes of the parametric system, so each configuration has to produce 31.50% perforation percentage by considering 30% plenum area of the building.
5. Conclusion

- Banji pattern characterizes the $p4gm$ symmetry group, while Kawung pattern on $p4mm$, Parang pattern on $p1$, and Nitik pattern on $c2mm$.
- On the photogrammetric stage, the digital three-dimensional meshes are successfully formed by using 13-19 overlapping photographs of the objects.
- Perforated batik pattern panels are generated and it is possible to set the perforation percentage to reach the desired WWR value.
- Further researches are needed to investigate the effectiveness of the energy use and the daylight performance of these shading devices.

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