Computational Aesthetics of Low Poly: [Re]Configuration of Form

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Abstract. Low-poly modeling as an emerging field in visual arts, product design and architecture has an essential effect both on the designer's and the viewer/user's experience. It has an advanced abstraction ability over the reconfiguration of form. This paper examines the visual features of low-poly form in terms of the computability of its aesthetics. A visual feature classification is made by referencing George David Birkhoff's aesthetic measure theory based on the complexity and order relationship. Topo[i]wall installation has been examined as a case study during the analysis. The relationship between form, computation, aesthetics and human-computer interaction are elaborated according to the results. It has been observed that low poly modeling offers a variation set in terms of compositional features, which are proportion, balance, vertical and horizontal network system while protecting its unity through the analysis of the generated computational model.

Keywords: Low poly, computational aesthetics, reconfiguration, form generation, Birkhoff's aesthetic measure

1 Introduction

Low-poly modeling is an emerging subject in the fields of visual arts, architecture and product design. Although it is usually used in the game industry to optimize computational power usage in virtual environments, it has become a popular form generation method for the design industry. It is a simple abstraction tool through the reconfiguration of the number of polygons. This reconfiguration method alters from software to software. The computational medium proposes a wide range of possible methods to create a low poly model. Thus, it also enables a variation set for the abstraction of a form. The aesthetic quality of abstraction in low poly modeling differs through computational operations and human perception. The main operation in low poly modeling, which reduces the polygon numbers, configures the complexity level called the level of details (LOD) in 3D graphics (Luebke, et al., 2002). Reducing the polygon numbers is not merely related to decreasing the complexity level. It is also oriented through reordering. Computational aesthetics historically base on these notions, order and complexity, defined as the primary measurement values for aesthetics by George David Birkhoff. Departing from Birkhoff's works, many aesthetic measurement definitions added to computational aesthetics theory. However, these theories remain argumentative since the definitions of aesthetics and aesthetic value vary in science, art and architecture. As machine learning and AI are -as research fields- on the rise, the topic has gained much importance to unfold the quest of the sensuous and perceptive qualities of form as measurable matters. Therefore, opening a gate towards investigating why low-poly modeling attracts the viewer and how this attraction can be classified in terms of aesthetics and computation to enlighten the human-computer interaction can initiate development in the field in terms of form reconfiguration.

2 Content

In this paper, the computational aesthetics of low poly is investigated concerning the reconfiguration of form. "Topo[i]wall" installation is used as a case study during this examination. The installation positions in front of an interior wall symbiotically. The design process of installation involves low poly modeling, digital fabrication and projection mapping techniques. While reconfiguring the form through low poly modeling, a variation set with different abstraction levels emerges. One of the satisfying results from this variation set is selected and then digitally fabricated and constructed as a low poly wall. The other possible variations are used as input for a projection mapping design. The mapping merges the physical and digital models of the low-poly form variations while interacting with sound.

Various aesthetics measurement methods starting from Birkhoff's theory are examined. Among them, Birkhoff's theory is reinterpreted through the "Topo[i]wall" case to understand the visual features of low-poly form in terms of computability. The study has four stages: (1) the investigation of computational aesthetics methods, (2) the investigation of methods used for the polygon reduction, (3) the design process of the case study (installation), (4) the analysis of the case study. The relationship between form, computation, aesthetics and human-computer interaction are elaborated according to the results. The study results will further be evaluated as a discussion starter for the relationship between computational aesthetics, form generation, reconfiguration of form and human-computer interaction.

2.1 Computational Aesthetics Methods

Birkhoff's aesthetic measure theory as the initial driver of the computational aesthetics field has influenced many disciplines' attitudes towards aesthetics, aesthetic perception and experience. The question of how to formulate and measure aesthetics could not be free from human perception. Hence, the topic has been an interest in psychology, philosophy, art, and architecture besides computer science. However, all these disciplines' approaches to the subject vary according to their definition of aesthetic. The etymological root of the word aesthetic is grounded in Greek; aisthetikos, which means "of or for perception by the senses, perceptive," of things (Online Ethymology Dictionary, 2021, 20 July). This ontological definition has been transformed from an understanding of a feeling to a science discipline in which the main interest is on the epistemological meaning concerning the conditions of sensuous perception starting from the 18th century (Spratt & Elgammal, 2014, Online Ethymology Dictionary, 2021, 20 July). Hence, to define aesthetics, many researchers and philosophers have worked on unfolding these "conditions" term to enlighten the nature of aesthetics and how it works as a matter of judgment (Baumgarten, 1961; Kant, 2000; Eshleman, 1968; Hoenig, 2005; Greenfield &Machado, 2012; Spratt & Elgammal, 2014).

The judgment of beauty, feeling and quality of an object, whether it is an art object or not, is linked to an observer who determines an understanding of aesthetic viewpoint. According to James Gips and George Stiny, although these understandings vary, they share a common ground where a classification or characterization is possible. A set of interpretative conventions and evaluation criteria may emerge throughout these characterizations (Gips& Stiny,1975). Gips & Stiny proposes a generation set for algorithmic aesthetics based upon shape grammars rather than concentrating on the conditions. The in-depth understanding of the aesthetics is predicated on formalizing the process as algorithms accordingly.

Although generating a recipe for aesthetics cannot be free from culture and social aspects, computational aesthetics studies the creative tools, aesthetic evaluation, perception, and meaning to develop the human-computer relation and machine intelligence; AI by defining aesthetics algorithmically (Suzuki et al., 2019, Zhang et al., 2012). Regarding the varying definitions, the aesthetics understanding in this paper embraces the conditions as states and the process as a generation. As aforementioned, this paper tries to understand and classify the aesthetic visual characters of the low poly modeling to initiate an understanding of the computability of a reconfigured form. Therefore, the cultural content is out of the scope and the main concern is on the aesthetic evaluation parameters of low poly modeling regarding Birkhoff's aesthetic measure theory.

2.2 Methods Used for The Polygon Reduction

Low poly modeling can be defined as a reconfiguration of a form by reducing the number of polygons. There is a local form defined as the original matter of the object transforming into a migrant form. This migrant form is also described as the reconfigured form in this paper. This process is a simple abstraction of the local form. The geometrical and topological qualities of the local form need to be evaluated according to the purpose of the reduction. Whether the purpose is the quest for an efficient geometry processing or a form-finding study, through LOD configuration, the local form transforms by various operators. There are several operators for polygon reduction -also called mesh simplification-; edge collapse (elimination), vertex collapse, vertex- pair collapse, triangle collapse, cell collapse, polygonal merging, vertex removal (elimination/ decimation) (Schroeder et al.1992; Wünsche, 1998; Luebke, et al., 2002). The complexity and reconfiguration level is based upon these operators, which function through various algorithms; vertex clustering, incremental decimation and resampling (Botsch et al., 2007). Among these operator's edge collapse and vertex removal logic has been used during this study via Blender and Rhino-Grasshopper software. The main operator component is called random reduce, which identifies the reduced vertices or faces. According to the list of items, after reduction, the mesh can be reconfigured.

2.3 The Design Process of The Case Study: Topo[i]wall Installation

Topo[i]wall emerges through a low poly surface generated through folded papers. The installation positions in front of an interior wall symbiotically. The form of the wall tries to embrace the viewer by spreading on the wall from ceiling to floor. The shadow and light balance changes during the whole day on the wall; hence, the aesthetic perception of the wall differs accordingly (Fig.1).

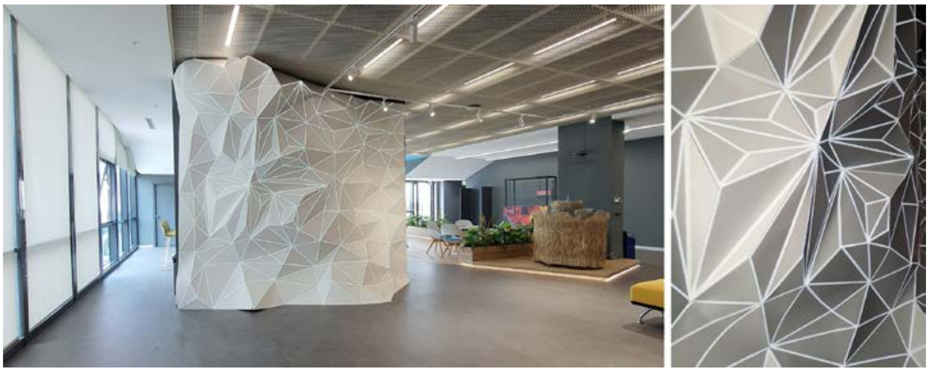

Figure 1. Topo[i]wall general view and detail photo (source: author)

The name of the installation refers to both topography and topology in mathematical terms. The topographical effect of the wall mainly works in the vertical direction. It acts like a topography of a tree from the side views spreading from floor to ceiling. The topology of the low poly surfaces changes and shifts, and at the end, an artificial landscape emerges (Fig.2).

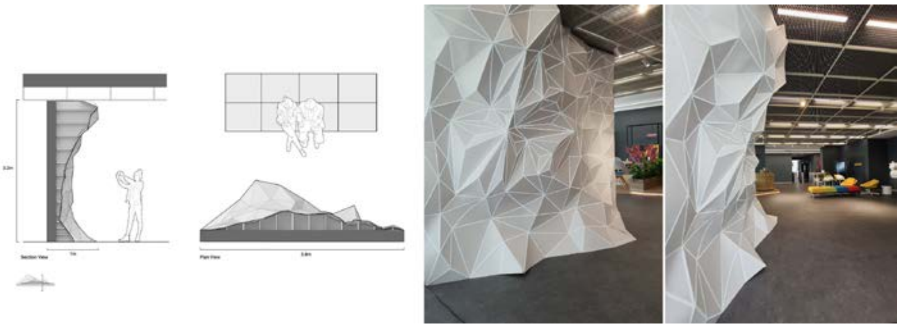

Figure 2. Topo[i]wall plan and section and its topographical effect (source: author)

Topo[i]wall design process indicates design sketches, digital and computational modeling, digital fabrication, building and projection mapping stages. The initial defined smooth mesh surface is reconfigured by using Blender and Rhino-Grasshopper software. The desired mesh that matches the initial design sketch's needs is built throughout the generated variations. The designers try to experiment with the reconfiguration of form generation by using low-poly surfaces. The main operation for this is the reduction of mesh surfaces. Besides the experimental approach to form generation, the other goal was to achieve a lightweight and economical architectural installation. Therefore, several strength tests were done according to the paper and structure properties. Digital, computational and physical models have been generated as input and output during the phases of the design process. The phases give feedback to the generated models, and accordingly, the design evolves (Fig.3).

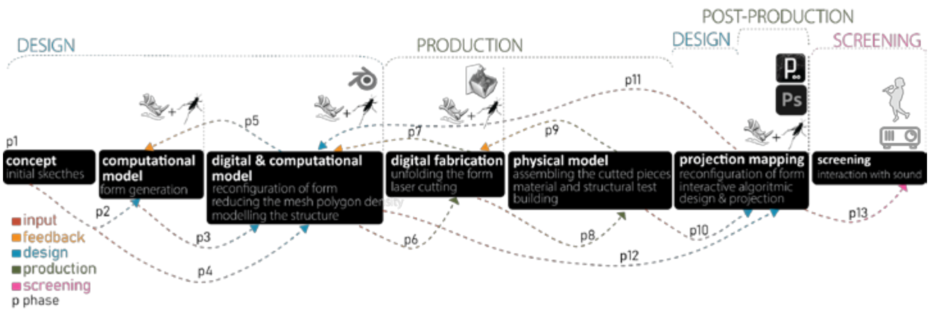

Figure 3. Design process of Topo[i]wall (source: author)

2.4 The Analysis of The Case Study

A visual feature classification is made due to the occurrence of the reconfiguration of form. This occurrence is two folds (1) the ones that arise during the design process, and (2) the ones that emerge with the effects of light and shadow on the wall (Fig.4). The features of the low poly wall are elaborated according to Birkhoff's aesthetic measure theory below.

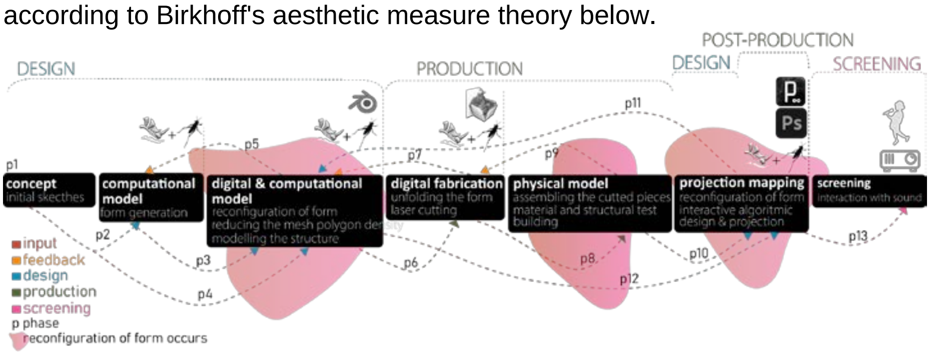

Figure 4. Reconfiguration of form phases in the design process (source: author)

Birkhoff constructs aesthetic measure (M) theory on the relationship of order (O) and complexity (C). According to him, the ratio of order and complexity reveals the aesthetic experience mathematically. He has worked on vases, polygons, music and poetry. The basic formula considers complexity as the attention given to perceive the object and the order is linked to harmony and symmetry (Birkhoff, 1933; Boselie & Leeuwenberg, 1985; Douchová, 2015). As the complexity level decreases, the aesthetic experience increase.

$$M= O/C \tag{1}$$

The elements of the formula change according to the evaluated object. For example, the order has elements as vertical symmetry (V), balance/equilibrium (E), rotational symmetry (R), horizontal-vertical network/grid (HV) and non-pleasing or unsatisfactory form (F) for polygon evaluations (Birkhoff, 1933).

$$M= V+E+R+HV-F/C \tag{2}$$

As it comes to vases, instead of balance/ equilibrium (E) and rotational symmetry (R) elements, Birkhoff positions tangent characteristics of the object to the formula as a matter of order(T) (Birkhoff, 1933).

$$M= +H+HV+T/C \tag{3}$$

Besides formulas (2) and (3), Birkhoff proposes other formulas to measure the aesthetics of ornaments and tilings, diatonic chords and harmony, melody and musical quality of poetry. However, he did not propose a formula for visual art and architecture. He classifies aesthetics as qualitative and quantitative. As he defines:

Qualitative aesthetics may be defined to be that part of aesthetics which traces the general nature of the associative network by furnishing a rough description of the aesthetic factors. (Birkhoff, 1933, p.210)

The associative network refers to the physiological nerve fibres of brain where a comparative aesthetic experience occurs. Therefore, redefining the aesthetic factors becomes crucial. Birkhoff holds the view that the characteristics of these factors cannot be determined definitely; instead, they can be estimated (Birkhoff, 1933). These estimations structure upon unity and variety concepts which are directly related to complexity and order. He expresses three major factors accordingly.

(1) Unifying without losing variety positively affects aesthetic measures, reducing complexity by protecting the order value.
(2) Creating variety without losing unity refers to increasing order value while protecting the complexity level.
(3) Unity in variety has to exist in the various parts of the whole.

Regarding this point of view, it can be said that the first reconfiguration of the Topo[i]wall in the design process suits the second occasion of the qualitative aesthetic factors of Birkhoff. While searching for an efficient geometry and form regarding fabrication issues and the contextual properties like the scale of the wall, height of the ceiling, direction of light etc., the unity is protected by creating various solutions. As the complexity level decreased, the design order increased in that manner (Fig. 5).

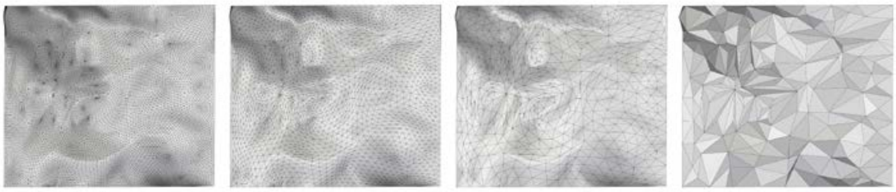

Figure 5. Decreasing the complexity level while protecting order, in other words creating variety without losing unity (source: author)

The reconfiguration of form during projection mapping suits the first occasion where the aim was to unify the variations as a whole. The final selected and built design's computational model is used as an input, and the mesh polygons' density is reduced while seeking the variations. The overlapping method is used to protect the harmony of the whole scenery. In other words, the order value is increased while protecting the complexity level (Fig. 6).

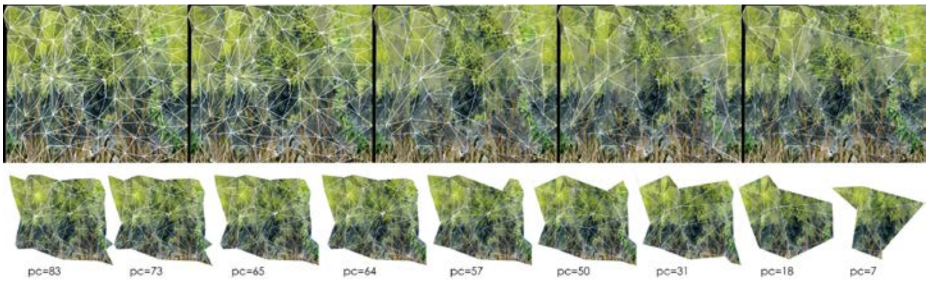

Figure 6. The polygon reduction while seeking for the variations and unified variations as a whole for projection mapping (source: author)

Birkhoff especially underlines the particular case of paintings, sculpture and architecture. These works involve many aspects besides formal elements of orders such as color, light, and shadow effects as environmental conditions, resulting in *numberless associations corresponding to connotative elements of order* (Birkhoff, 1933). He makes an analysis of Correggio's 'Danae' in terms of divisions and directions regarding composition. According to him, a good composition needs to be comprehended easily. This also refers to the main idea of the aesthetic measure in which complexity means the effort of attention of the viewer. Topo[i] wall's composition is elaborated due to the vertices of the polygons to understand the characteristics of the order. A feature classification is made due to proportion, horizontal-vertical network and balance relation.

The primary need is a center of interest and sub-centers in a composition (Birkhoff, 1933). Like in the rule of thirds or golden ratio, the center of interest attacks the viewer while creating foreground and background boundaries/passages hierarchically. Topo[i]wall has one primary center of interest and eight subcenters. The vertical and horizontal network created from the vertices indicates the density of vertices in the X-Y axis. The lines get closer and look duplicated because of the placement of the vertices. Although some of the vertices seem coincident either on the Y or X coordinate, they are not. In terms of the balance of the network, a reorganization can be done about these positionings. Another point that needs to be underlined is the proximity of centers to the vertex classes (Fig. 7). It can be seen that when the centers get closer to the vertex classes, the density of the vertices rises.

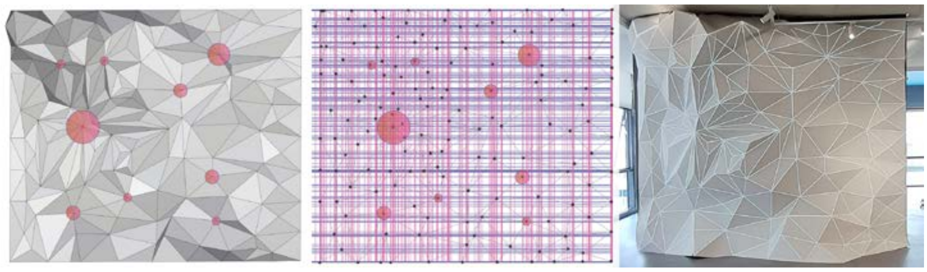

Figure 7. The point of interests and their relationship with a vertical and horizontal network (source: author)

An algorithm is created to eliminate duplicated line clusters. The network is associated with a canvas resolution, and the main parameter is defined as resolution tolerance. As the resolution tolerance rises, the non-coincident lines vanish. A color-coding is added to differentiate the density of the vertices and their relation with the center of interests. Pink refers to dense vertex classes, blue shows lighter districts in the below analysis (Fig. 8).

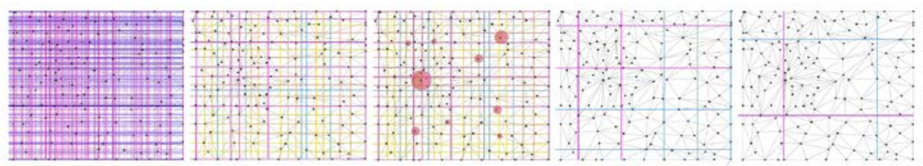

Figure 8. The redefined network system after removing the non-coincident lines and their relationship with the center of interests (source: author)

As the second fold of reconfiguration of form, light and shadow effects need to be elaborated. Rudolf Arnheim defines this fold as the aesthetic attitude in perception. He points out that environmental conditions like morning or evening light expose an object's varying states, which causes richness of sight as the intelligence of perception (Arnheim, 1969). Birkhoff defines these varying states as the balance of color or light and dark values affecting the center of interests. Topo[i]wall acts as a dynamic entity through the movement of light and shadow effects (Fig. 9).

Figure 9. The varying states of the wall and the reconfigured perception through light and shadow effects (source: author)

3 Conclusion

Low poly form generation offers an insight towards computational aesthetics with its advanced abstraction ability through the reconfiguration of form. While computational aesthetics challenges form generation and artificial intelligence, understanding why low-poly modeling attracts the viewer and how this attraction can be classified in aesthetics becomes crucial. This paper attempts to initiate an in-depth visual feature classification to encode the language of low-poly form in terms of aesthetics. The analysis of the case study is made according to Birkhoff's aesthetics measure theory.

Birkhoff classifies visual arts and architecture within the qualitative aesthetic theory factors. According to that, unity and variety come to prominence while unfolding the aesthetic qualities of the form. The ratio relationship of order and complexity defining aesthetic measure is reconstructed through unity and variety notions. The case study analysis reveals varying conditions through the reconfiguration of form that occurred during the design process. This reconfiguration enhances a human-computer interaction (1) while reducing the polygon numbers, (2) throughout perception of the object within its context and (3) through the sound interactive projection mapping. The generated computational models gather the variations within a unity. Therefore, it can be said that the medium of the design also transforms into an aesthetic entity.

It has been observed that low poly modeling offers a variation set in terms of compositional features, which are proportion, balance, vertical-horizontal network system, while protecting its unity through the analysis of the generated computational model. The analysis shows that the design order increased in Topo[i]wall as the complexity level decreased. However, the generated computational model to analyze the vertical-horizontal network exposes the proportional issues of vertex positions. The generated computational model can be reevaluated and the reconfiguration can be repeated due to the feedback.

The study also shows that creative switches emerged through human-computer interaction during the design process of the Topo[i]wall concerning the unification of the variations of design, especially in the projection mapping phase. These creative switches are perceived/interpreted as aesthetic emergence of the unexpected outputs generated through the computational model. Although computational creativity is not the subject of interest in this paper, it can be said that a further study can be developed regarding designer moves and aesthetic experience during the computational design process.

Consequently, the results of this study will be used as an input for the computerization of a rule-based approach and the structure of an empirical study for human perception of low-poly aesthetics in further studies.

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