Birkhoff's Aesthetic Measure and Common Aesthetic Values in Digital Design

Hafizah Abdullah Ali[1], Husniza Husni[2]

[1]Department of Design and Visual Communication, Politeknik Tuanku Syed Sirajuddin, 02600 Pauh Putra, Malaysia.
hafizahict@gmail.com
[2]School of Computing, Universiti Utara Malaysia, 06010 Sintok, Malaysia.
husniza@uum.edu.my

Abstract: This paper reviews the aesthetics of digital design concerning Birkhoff's Aesthetic Measure, which is an important aspect that would lead to better usability, visual elements, and perceived user experience. With limited literature focusing on aesthetics, this paper conducted a systematic literature review to uncover the primary and standard aesthetics measures that can be used to measure digital design's 'appealing-ness.' The findings revealed fourteen common aesthetic values using Birkhoff's Aesthetic Measure that is related to screen and digital design, which is the scope of this review. These shared values can be used in measuring the aesthetics of any digital artifact, including a digital graphic novel. From the fourteen, five measures are exciting to be explored further concerning digital graphic novels as discussed. It is a significant finding to establish a common and standard measure of the aesthetic in digital design and, therefore, in digital graphic novels.

INTRODUCTION

One way to increase the usability of digital design is by improving the appearance of interface design [1]. The research reported here relates to evaluating the aesthetic value for a digital design using Birkhoff's Aesthetic Measure (BAM). The term aesthetic relates to the study of appearance in art, beauty, and appeal [2][3] they are seen as an impression that changes with external circumstances such as age, culture, health, experience [4][5], as well as emotional appeal [6]. BAM is a quantitative approach to several aesthetic values [7][8][9].

In the field of interaction design, aesthetic considerations are required. This paper looks at measuring aesthetics in digital work, specifically Digital Graphic Novel (DGN). How to practice BAM in measuring the aesthetic, and what are the aesthetic values in a digital work? Answering these questions is the aim of this paper and hence the objective is to review the aesthetics of digital design. We will discuss the visual aesthetics in the context of DGN design with respect to BAM.

AESTHETIC MEASURE

Aesthetic measurements, according to Birkhoff [10], are the relation of order and complexity. He proposed the Aesthetic Measure in 1928, attempting to quantify aesthetic by defining it as the ratio of order (O) to complexity (C), particularly $M = O/C$, with greater M denoting higher aesthetic measure.

Using the BAM formula, the aesthetic measure, M from an information theory point of view, will be measured [11], in this case, the concepts of O and C in designing DGN. O will calculate all the components included in each aesthetic value, such as text, image, panel, and related features for specific aesthetic value in each interface. The measure proposed that the more order an object possesses for a certain complexity level, the higher its aesthetic measures will be. For a particular order, an object is considered more aesthetic if it is less complex. As such, it will provide significant implications for both DGN researchers and practitioners in measuring DGN products using BAM.

According to the previous study on aesthetics, we can refer to a framework by [12] as depicted in Fig 1. He

Corresponding Author: Hafizah Abdullah Ali, Politeknik Tuanku Syed Sirajuddin, +60125014371

constructed a framework that focuses on the relation between aesthetics and designing digital work.
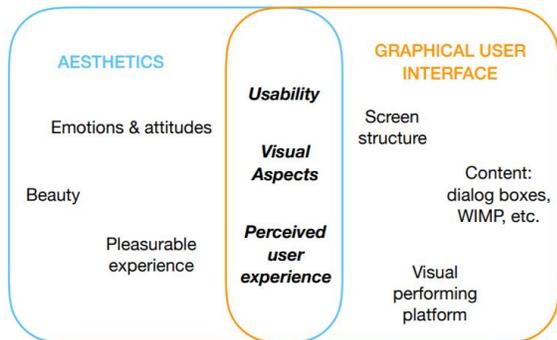

Fig 1 General framework related to the aesthetics and graphical user interface. Source: [12]

Referring to Fig 1 can be seen the elements of aesthetics or aesthetic features that are disengaged from the graphical user interface (GUI) in a digital design – emotions and attitudes, beauty, and pleasurable experience. While usability, visual aspects, and perceived user experience hold for aesthetics and GUI as often demonstrated by best products [13].

METHOD OF STUDY

To achieve the objective of this paper, the Systematic Literature Review (SLR) is employed. SLR is a method of analyzing and understanding all available research relevant to a specific research problem, topic, or phenomenon [14][15]. SLR provides methodological advantages and applications for research issues [16]. Hence, the review methodology establishes three subsequent steps for conducting a systematic literature review, as presented in Fig 2.
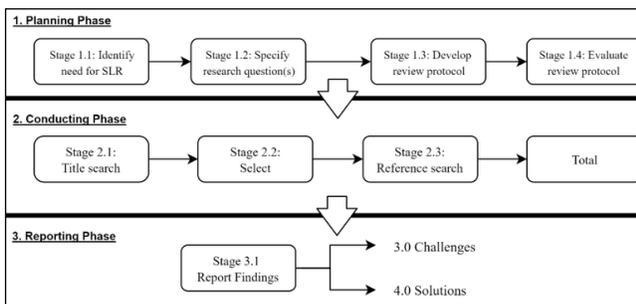

Fig 2 Steps for conducting Systematic Literature Review

Planning Phase

The first phase begins with the formulation of the research objectives where the needs for SLR are identified. Specifying research questions and developing a review protocol for this research is the best

strategy to accomplish this goal. The following are the research questions defined before conducting the SLR:

RQ1: What is the practice of Birkhoff Aesthetic Measure?
RQ2: What are the common aesthetic values using Birkhoff's Aesthetic Measure?

Examining BAM's practice to measure aesthetics for digital design is significant as we want to select one measurement that could give empirical evidence to the aesthetics of a DGN. Therefore, the shared values of such measures must also be reviewed so we can select the most relevant ones concerning digital design, specifically DGN.

Conducting Phase

In the second phase, the process begins with a related research searching process. It starts with a search of previous research titles and summarizes the content of reviews based on specific keywords. Then, the search is more pitched towards the research question. The keywords used include "Birkhoff's aesthetic measure", "aesthetic measure + digital design", "aesthetic measure + screen design", "aesthetic measure + digital design" and "aesthetic measure". Only 35 sources are chosen from 97 sources found from online database searches, and they can be divided into multiple groups using the screening technique indicated in Fig 3.
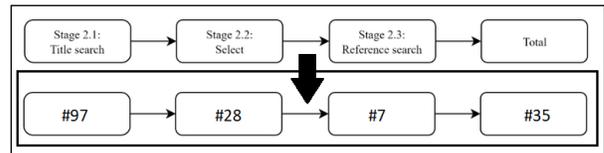

Fig 3 Number of papers at the screening process

The selection process is based on two criteria, namely inclusion and exclusion. The protocol review criteria to be selected in the primary studies are as shown in Table 1 based on the research questions.

Table 1 Inclusion and Exclusion Criteria

Inclusion	Exclusion
Conference or journal between 2016-2021.	Conference or journal before 2016.
Screen design guidelines.	Non-digital design guidelines.
Birkhoff's Aesthetic Measure, Measure Aesthetic for digital	Aesthetic measure for

design, Measuring Aesthetic using Birkhoff Aesthetic Measure.	non-digital design.

A database has been created to facilitate data management from selected studies. Many resources are obtainable through electronic libraries, resulting in a relevant publication. The search on the following databases is recorded: ACM Digital Library, IEEE Xplore, Elsevier Scopus, JSTOR, ResearchGate, Semantic Scholar, Springer, and Wiley Online Library.

Reporting Phase

In the final phase of the SLR, the study questions are critically discussed and reported in the next section.

ANALYSIS AND FINDINGS

The final list includes articles published between 2016 and 2021, 28 sources were selected, and seven sources are regarded as the primary reference due to the use of theories and research results that were highly accurate and answered the research questions. The selected papers are classified based on the specific research questions. It is important to note that this research still has significant references within the scope of the most recent five-year study. Studies leading to the measurement of aesthetic value using mathematical measurements, specifically in digital works using BAM, are limited and yet necessary.

RQ1: What is the practice of Birkhoff Aesthetic Measure?

According to Birkhoff, the aesthetic measure is composed of three phases: 1) a preliminary effort of attention, which is required for the act of perception and increases proportionally with the complexity (C) of the aesthetic values; 2) the sense of value or aesthetic measure (M) that rewards this effort, and 3) the verification that a specific order characterizes the aesthetic value.

$$M = O / C, (C > 0)$$

Various fields use BAM in assessing aesthetic value. Fig 4 shows the percentage of lots that practice BAM.
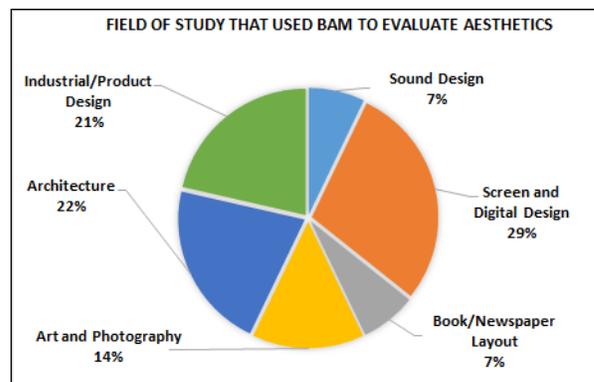

Fig 4 Field of studies that use BAM to evaluate aesthetics

Based on Fig 4, past studies have frequently linked three areas to aesthetic measurement using BAM: Industrial/Product Design, Architecture, and Screen and Digital Design. Screen and Digital Design is the field with the highest aesthetic value measured using a mathematical evaluation covering 29%. It shows that aesthetic measurement using mathematical equations is still relevant and suitable for screen design for digital design and, therefore, specifically for DGN.

RQ2: What are the common aesthetic values using Birkhoff's Aesthetic Measure?

To investigate the above research questions, 11 studies were identified, and the common values are presented in Table 2 according to the reviews on the literature.

Table 2 Common aesthetic value using Birkhoff's Aesthetic Measure

Source	Aesthetic value	Description
[1], [14], [15], [16], [17], [18], [12], [19], [20], [21], and [22]	Measure of balance	Distribution of optical weight in a picture.
[1], [14], [15], [18], [12], and [21]	Measure of equilibrium	Equilibrium on a screen is accomplished through centering the layout itself. The centre of the form coincides with that of the frame.
[1], [14], [15], [17], [12], [19], [20], [21], and [22]	Measure of symmetry	The screen is symmetrical in three directions:

		vertical, horizontal, and diagonal.
[1], [14], [15], and [17]	Measure of sequence	The arrangement of objects in a layout in a way that facilitates the movement of the eye through the information displayed.
[14]	Measure of Cohesion	Aspect ratios promote cohesion.
[14], [17],[18], [12], [19], [21], and [22]	Measure of Unity	Unity is achieved by using similar sizes, shapes, or colors for related information and leaving less space between elements of a screen than the space left at the margins.
[14], [16], and [12]	Measure of proportion	Aesthetically pleasing proportions should be considered for significant screen components, including windows and groups of data and text.
[14], [17], [18], and [12]	Measure of simplicity	Combination of elements in a form.
[14], [17], [19], and [22]	Measure of density	Character positions on the entire frame containing data.

[14]	Measure of regularity	Standard and consistently spaced horizontal and vertical alignment.
[14], [17], and [22]	Measure of economy	Styles, displays techniques, and colors.
[14]	Measure of homogeneity	Measure how evenly the objects are distributed among the quadrants.
[14] and [17]	Measure of rhythm	Regular patterns of changes in the elements.
[1], [14], [15], [16], [18], [12], [19], [20], and [22]	Measure of order and complexity	Order is written as the sum of the design complexity.

Based on the standard aesthetic measures, this research drew the list of aesthetic considerations mainly from existing graphic design principles [23], [24], [25] and screen design guidelines [26], [27], [28] as the following. These studies used a standard aesthetic measure for screen design that was closely related to digital design. Five aesthetic steps are considered significant based on the frequency of use for each aesthetic value in previous studies. Based on 11 primary pieces of literature, these five measures occurred in more than half of the studies listed in Table 2.

Measure of balance

Balance is where the use of the image or content on the screen is in a balanced composition. It can increase the attractiveness of the user's eyes [21]. To balance the composition, the positive elements and the negative spaces must be arranged so that none of the design parts dominates the other.

Measure of equilibrium

Equilibrium refers to the layout or the arrangement of the contents on a page. According to Ngo et al. [15], when the layout is centered, it achieves balance and can thus be superposed with the frame center.

Measure of symmetry

According to Huang et al. [29], symmetry is the exact form or object correspondence on opposing sides of a center or axis.

Measure of Unity

Unity is defined as the perception of the whole visual element in the layout [30]. With unity, the details appear to belong together, to fit together so perfectly that they are perceived as one thing. Unity is achieved by using similar sizes, shapes, or colors for related information and leaving less space between screen elements than the margins.

The measure of order and complexity

Order and complexity refer to the layout of the screen's elements [14], [12]. Hence, the measure of order and complexity is the total value of all combinations of aesthetic values.

These five measures are significant for measuring the aesthetics of a DGN. Based on the result from previous studies, these five measures are often used as the importance and primary measures for aesthetic design for digital screens and can be expanded into DGN design.

CONCLUSION

This paper presents an SLR study to answer questions related to aesthetic measures and aesthetic values as aforementioned. From the SLR conducted, we can say that BAM is prominently used to measure aesthetics in the screen and digital design field, apart from other areas. From the field of study, we have found 14 common aesthetic values related to DGN. These values are using BAM to measure its aesthetics. This shed some insights and direction to measure the aesthetics of a DGN and the elements that should be of concern when designing and developing the DGN. Nonetheless, it raises questions as to how these values are measured using BAM. Therefore, we attempt to select the elements/values for each aesthetic measure for the DGN design in future studies. Consequently, they must be listed in depth to facilitate the calculation of values using the BAM formula.

REFERENCES

[1] Ngo, D. C. L., & Byrne, J. G. (1998, December). Aesthetic measures for screen design. In Proceedings 1998 Australasian Computer-Human Interaction Conference. OzCHI'98 (Cat. No. 98EX234) (pp. 64-71). IEEE.

[2] Brielmann, A. A., & Pelli, D. G. (2018). Aesthetics. Current Biology, 28(16), R859-R863.

[3] Arumugam, K., & Ali, R. M. (2019). Buku kanak-kanak: Analisis unsur Estetika. PENDETA: Journal of Malay Language, Education and Literature, 10, 151-165.

[4] Brady, B. E. (2019). Aesthetics of the natural environment. Edinburgh university press.

[5] Keong, L. (2019). The Impact of Virtual Simulation on Aesthetic Experience in Human Psychology and Perception.

[6] Liu, P., Wang, K., Yang, K., Chen, H., Zhao, A., Xue, Y., & Zhou, L. (2020). An Aesthetic Measurement Approach for Evaluating Product Appearance Design. Mathematical Problems in Engineering, 2020, 1–15. https://doi.org/10.1155/2020/1791450

[7] Khalili, A., & Bouchachia, H. (2021). An information theory approach to the aesthetic assessment of visual patterns. Entropy, 23(2), 153.

[8] Meddahi, K., & Boussora, K. (2021). Aesthetic Measures of Algiers' Colonial Facades. Nexus Network Journal, 1-22.

[9] Johnson, C. G., McCormack, J., Santos, I., & Romero, J. (2019). Understanding aesthetics and fitness measures in evolutionary art systems. Complexity, 2019.

[10] Birkhoff, G. D. (1933). Aesthetic Measure by George D. Birkhoff.

[11] Beebe-Center, J. G., & Pratt, C. C. (1937). A test of Birkhoff's aesthetic measure. The Journal of General Psychology, 17(2), 339-353.

[12] Botermans, C. (2017). Analysis of Graphical User Interfaces Aesthetics based on Visual Metrics. Masters Thesis. Université Catholique de Louvain.

[13] Saffer, D. (2010). Designing for interaction: creating innovative applications and devices. New Riders.

[14] Ngo, D. C. L., Samsudin, A., & Abdullah, R. (2000a). Aesthetic measures for assessing graphic screens. J. Inf. Sci. Eng, 16(1), 97-116.

[15] Ngo, D. C. L., Teo, L. S., & Byrne, J. G. (2000b). A mathematical theory of interface aesthetics. In Visual mathematics (Vol. 2, No. 4). Mathematical Institute SASA.

[16] Cleveland, P. (2008). Aesthetics and complexity in digital layout systems. Digital Creativity, 19(1), 33-50.

[17] Altaboli, A., & Lin, Y. (2011, July). Objective and subjective measures of visual aesthetics of website interface design: the two sides of the coin. In International Conference on Human-Computer Interaction (pp. 35-44). Springer, Berlin, Heidelberg.

[18] Kurnianto, A. (2013). Analisis Layout Surat Kabar berdasarkan Prinsip-Prinsip Desain melalui Metode Estetika Birkhoff. Humaniora, 4(2), 986-994.

[19] Khalili, A. M. (2017). On the mathematics of beauty: beautiful images. arXiv preprint arXiv:1705.08244.

[20] Van Geert, E., & Wagemans, J. (2020). Order, complexity, and aesthetic appreciation. Psychology of aesthetics, creativity, and the arts, 14(2), 135.

[21] Saputro, D. M., & Rito, B. B. R. (2020). Evaluasi Kualitas Estetika Fasade Bangunan dengan Pendekatan Birkhoff Aesthetic Measure. Journal of Appropriate Technology for Community Services, 1(1), 1-5.

[22] Mbenza, P., & Burny, N. (2020, June). Computing aesthetics of tangible user interfaces. In Companion Proceedings of the 12th ACM SIGCHI Symposium on Engineering Interactive Computing Systems (pp. 1-8).

[23] Landa, R. (2018). Graphic design solutions. Cengage Learning.

[24] Kamaruddin, N., & Sulaiman, S. (2018). Understanding interface design principles and elements guidelines: A content analysis of established scholars. In Proceedings of the Art and Design International Conference (AnDIC 2016) (pp. 89-100). Springer, Singapore.

[25] Li, Z. (2019). Application research of digital image technology in graphic design. Journal of Visual Communication and Image Representation, 65, 102689.

[26] Mayhew, D. J. (1991). Principles and guidelines in software user interface design. Prentice-Hall, Inc.

[27] Johnson, J. (2020). Designing with the mind in mind: a simple guide to understanding user interface design guidelines. Morgan Kaufmann.

[28] Ruiz, J., Serral, E., & Snoeck, M. (2021). Unifying Functional User Interface Design Principles. International Journal of Human-Computer Interaction, 37(1), 47-67.

[29] Huang, Y., Lyu, J., Xue, X., & Peng, K. (2020). Cognitive basis for the development of aesthetic preference: Findings from symmetry preference. PloS one, 15(10), e0239973.

[30] Alsudani, F., & Casey, M. (2009). The effect of aesthetics on web credibility. People and Computers XXIII Celebrating People and Technology, 512-519.