Chapter 2
On the Legitimacy of Quantifying Aesthetics

Is it legitimate to quantify aesthetics? Aesthetics is thought to be a matter of subjectiveness; on the other hand, design may not be found in formulas. For instance, Jason K. McDonald states "One reason design formulas and routines are inadequate is because design so often addresses the untried, the unproven, and the unknown" [32]. However, we believe that with advances in computing, the phenomenon of big data, and, more importantly, the fundamental difference between art and visual design, it is possible to quantify aesthetics of visual design.

In this chapter, we first discuss the theoretical considerations about aesthetics and then offer a taxonomy of quantifying aesthetics in the fields of computer science/engineering, psychology, and neuroscience.

2.1 Theoretical Considerations

Aesthetics of art is historically a subject of dispute between philosophers and art theorists. Korsmeyer in her book *Aesthetics: The Big Questions* [25] collects some of the fundamental questions about aesthetics of art, such as what is aesthetics, what can we learn from aesthetics and art, who decides what is art, and what is aesthetically pleasing. Korsmeyer also collects several essays and different viewpoints of philosophers to elucidate thinking about the aesthetic questions.

Korsmeyer summarizes two opposite doctrines about aesthetics, one which conceptualizes aesthetics as a matter of pleasure and taste and the other which considers aesthetics as a matter of cognition and hence learning processes. Korsmeyer accounts for the former by referring to earlier philosophers such as Plato in his book the *Republic* and later philosophers such as Immanuel Kant and his *The Critique of Judgment* and for the latter, by referring to Aristotle in his *Poetics* and contemporary philosophers like Hans-Georg Gadamer. While the former doctrine has been the

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major belief until the eighteenth century, the latter is recently dominating the disputes. Therefore, there are increasing attempts to learn from art and aesthetics.

Perhaps because of the advances in technology and the fact that digital media is becoming an inevitable part of our everyday life, the idea that we can learn from aesthetics needs more attention. Udsen et al. [46] articulate that we are witnessing the "aesthetic turn" and delineates four major contributions of aesthetics in information technology and design of human–computer interaction: cultural, functionalist, experience-based, and techno-futurist. On the cultural level, we are witnessing that the computer is serving as a medium engaging us in experiencing digital media and art in our daily life. In the functionalist approach, aesthetics enables higher levels of behavioral functionalities and enhances the usability of computers. On the experience-based level, aesthetics nurtures emotions and creativity in design of interactions. The rather youngest of all other three levels, the techno-futurist approach, is the influence of the technological human reflecting on technology which in turn defines new ways of interactions between computers and humans.

Donald Norman in his book *Emotional Design: Why we love (or hate) everyday things* [38] delineates three levels of aesthetic cognition: visual, behavioral, and visceral. The visual level is the first and immediate level of aesthetic cognition; for example, when we see a beautiful flower, we may appreciate its visual appeal. The behavioral level deals with the situation when we like how an artifact is functional and usable. The visceral level needs more patience; for instance, when we solve a mathematical problem or when we contemplate an artwork and after a while, we understand it (the Aha moment).

Quantifying aesthetics in visual design is more plausible than in visual arts: Unlike visual arts where the main goals may be abstract, visual design is conceptualized and created to convey a message and communicate with audiences [3, 4, 11, 16, 17, 20, 21, 35, 39, 47]. This is a key but subtle difference. In fact, it is a critical measure of success in applied arts along with the visual appeal of the design. A design message has to be conveyed at first glance. Studies suggest that designers need to make a good first impression only in some few milliseconds [27, 28], and this impression deals with expressive aesthetics [44]. These qualities suggest that it is theoretically legitimate to evaluate a visual design and argue if it is a good design or not. In other words, an artwork may be considered as "high" or "low" art (descriptive terms from Korsmeyer [25]), but a visual design—as a very specific instance of art—may be considered as "good" or "bad."

Although it is legitimate to distinguish a visual design as good or bad, it is much easier to identify a bad design rather than a good one. Part of the reason is the fact that there is not only one good design. For a given task in design, designers may create several alternatives. A bad design, on the other hand, is easier to distinguish, especially when it does not follow the principles of design in a professional way. On such an occasion, design critics may argue that, for instance, this design "is not visually balanced" or "colors are not chosen carefully." This inspires us to strive to understand what visual balance is and to what degree a design is balanced. A similar question is raised for other elements of design, for example, color and type. In this thesis, we raise and answer some of the questions regarding quantifying aesthetics of visual design, but first, in the following section, we provide a taxonomy on quantifying aesthetics.

2.2 Taxonomy

In this section, we present a taxonomy on quantifying aesthetics based on our recollection of prior work. Figure 2.1 illustrates an schematic view of this taxonomy. To us, there are two main approaches to quantifying aesthetics: human inspection and automatic. By human inspection approach, we mean the set of empirical studies based on human judgments. This approach is well established in psychology. The main goal is to accept or reject a hypothesis by capturing responses of participants to a set of stimuli, under very specific conditions. The automatic approach, on the other hand, tries to evaluate aesthetics through closed-form mathematical expressions and artificial intelligence approaches such as pattern recognition/machine learning and evolutionary computing.

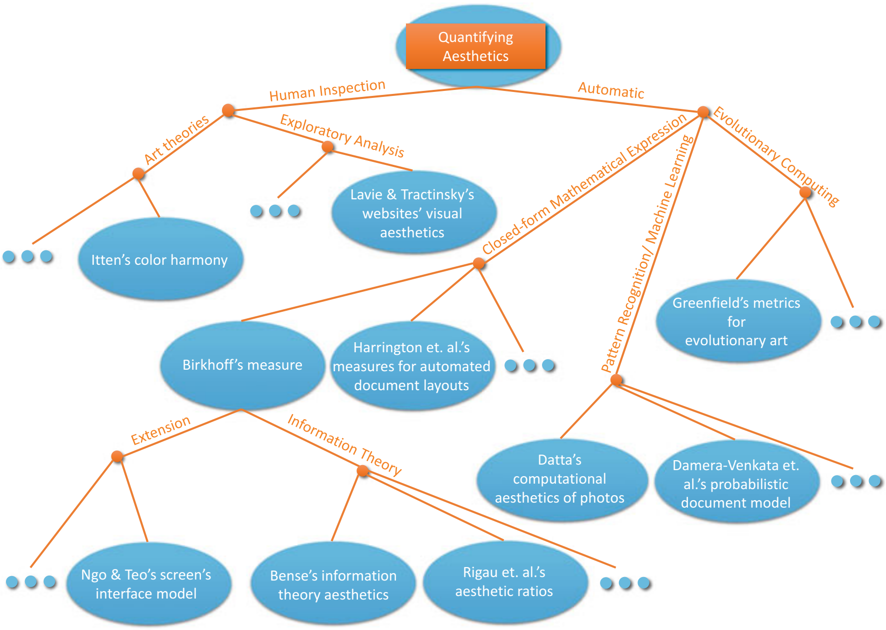

Fig. 2.1 Taxonomy of quantifying aesthetics: a schematic view. Refer to [7, 9, 10, 13, 18, 26, 31, 36, 37, 40]

Nevertheless, as we discuss in the following, both approaches may inspire each other. For instance, a series of studies in human inspection may lead to a ground truth for an automatic clustering, or a closed-form mathematical solution may steer a trend of research in empirical studies.

2.2.1 Automatic Approaches

One of the earliest attempts in quantifying aesthetics is perhaps Georg Birkhoff's measure:

$$M = \frac{O}{C}. \tag{2.1}$$

Birkhoff in his book *Aesthetic Measure* [7] argues that:

The typical aesthetic experience may be regarded as compounded of three successive phases: (1) a preliminary effort of attention, which is necessary for the act of perception and which increases in proportion to what we shall call the *complexity* (C) of the object, (2) the feeling of value or *aesthetics measure* (M) which rewards this effort, and finally (3) a realization that the object is characterized by a certain harmony, symmetry, or *order* (O), more or less concealed, which seems necessary to the aesthetic effect (Birkhoff [7], Chap. 1, Sect. 2, p.3).

Birkhoff's measure is general and implies that when complexity of a piece increases, its aesthetic value decreases. He applies this measure to quantify aesthetics of polygons, ornaments and tiles, vases, music, and poetry. Later, Bense [5], from an information theory perspective, applied redundancy theory for describing order and Shannon's theory for complexity [12]. Also, Rigue et al. [40] define a set of aesthetic ratios based on information theory and apply it to evaluate van Gogh's painting style [41].

Another recent extension of Birkhoff's measure belongs to Ngo et al. [36, 37] for measuring aesthetics of screen interfaces. In their model, order is a linear summation of thirteen measures such as balance, sequence, and rhythm.

From a psychological approach, Berlyin [6] studies the relation between complexity and aesthetics. Berlyin proposes a downward U-shaped graph to express the relation of complexity with aesthetics. He argues that when a piece is too simple or too complex, its aesthetic cognition decreases. A historical review on Birkhoff's measure and its branches is provided by Gary Greenfiled in [12].

We enumerate some of the other closed-form mathematical expressions. Machado and Cardoso [31] present an implementation of a theory of image processing aesthetics in which image complexity is proportionally, and processing complexity, inversely related to aesthetics. In computing aesthetics of automated documents, Harrington [15] suggests a measure as a nonlinear combination of design features in the page layout. For computing visual balance of an image, Lok and Feiner [30] suggest a measure based on lightness weight maps computed from the image. Balinsky [2] proposes a measure of symmetry in screen interfaces. Klinger and Salingaros [22] propose a measure for evaluating aesthetics (in terms of interestingness) of a pattern based on variety and symmetry of elements in a pattern.

Automatic approaches in quantifying aesthetics are evolving by advances in pattern recognition/machine learning and evolutionary computing in artificial intelligence. Datta et al. [10] suggest a computational model for photographic images based on a set of features such as low-level color features, distinct regions in an image, spatial composition, and depth of field in photography. Damera-Venkata et al. [9] propose a probabilistic document model for automated document layouts in which some design decisions for the page layout are included. In evolutionary computing, Greenfield defines several aesthetic metrics in optimizing the achievement of evolved visual imageries [13, 14]. Ross et al. [42] also use an aesthetics model (the *Painting Bell Curve* by Ross, the first author) in synthesizing evolutionary images.

2.2.2 Human Inspection Approaches

Itten [18, 19] was a color theorist who endeavored to bring color harmony from the realm of subjection to objection. Itten defines seven kinds of color contrast: contrast of hue, light-dark contrast, cold-warm contrast, complementary contrast, simultaneous contrast, contrast of saturation, and contrast of extension. Later, Mastuda extends the concept of color harmony and defines harmonious hue and tone templates [8, 43]. Kobayashi is another color theorist whose *Color Image Scale* [23, 24] in associating colors with linguistic concepts (color semantics) is well received. There exist other well-known theories on other visual design principles. In visual balance, for instance, Arnheim quantifies a structural net that contributes to a balanced spatial composition [1]. From a psychology and neuroscience perspective, scientists have studied and validated Arnheim's net through experimental and statistical analysis (see, e.g. [29, 33, 45]).

Through exploratory factor analysis, Lavie and Tractinsky [26] propose a measurement instrument for both classic (usability and behavioral) and expressive (beauty and visually pleasing) aesthetics. Their measures are inferred from a collection of user experiments on websites. Moshagen and Thielsch [34] also delineate a set of visual aesthetic factors under four categories of simplicity, diversity, colorfulness, and craftsmanship.

2.3 Conclusion

In this chapter, we discussed the theoretical considerations on the legitimacy of quantifying aesthetics. We summarized that although some art philosophers believe that aesthetics is a matter of taste, others (and especially contemporary philosophers) argue that it is a matter of cognition and hence learning. We then presented our taxonomy of quantifying aesthetics, based on our recollection of prior work in the fields of computer science/engineering, psychology, and neuroscience. We conclude that quantifying aesthetics is not only viable but an urge in leveraging adoption of art and media in our contemporary life.

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