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Design for aesthetics: interactions of design variables and aesthetic properties

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Abstract- This paper proposed a systematic approach for exploring the interactions of aesthetic properties and designvariables, by integrating knowledge from other fields such as philosophy, psychology and arts. Commonly-accepted aesthetic properties and language terms used for evaluation and criticism are first discussed and a common set of nine principles for achieving aesthetic products in a number of creative disciplines is identified. We then analyse the way these principles influence product characteristics and extract concrete and computable properties of products that may be varied to induce different aesthetic judgements and responses.
Keywords: computer-aided design, design for aesthetics, aesthetic factors.

I. INTRODUCTION

Much research work on design has been focused on how to satisfy constraints that are largely objective and measurable such as functionality, manufacturability, economy, efficiency and technicality. Although there is an increasing demand to produce objects that are more artistic pleasing, the integration of aesthetic factors to design has been very slow. The main difficulty is that aesthetic factors are subjective and efforts to date have been made in an ad hoc manner. To make any significant progress, a systematic approach is essential. While a designed product can trigger definite aesthetic responses to observers, it is not easy to relate these responses to the characteristics of the product. One reason is that the language to describe aesthetics is very rich, diverse and fuzzy, where one term may have a number of meanings to different people, or many terms may imply the same or very similar meaning. Another reason is that many different characteristics of the product may act singly or in combination to evoke the responses. Furthermore, the responses may depend on other factors besides the product itself such as previous experiences or cultures of the observers. We thus need to identify the characteristics of aesthetics and of products that are relevant to the task of design for aesthetics. The term 'aesthetics' is broadly used to describe the characteristics of the appearance of a design. In particular, it refers to the responses that indicate the degree of discrimination in perception when people are confronted with the design. This perception depends on individual interpretation which may arise from emotional responses and / or comparison with previous experience. In his "The Elements of Drawing" (1957), Ruskin 18 discussed the contrasts between the discriminatory manner of this type of perception (e.g. by artists) and the cursory manner of normal perception. The latter type is more utilitarian and ignores information that is not essential for everyday life. He also argued that "the appreciation of beauty is not a matter of judgement, but of response". The concepts of 'style', 'fashion', 'taste' and 'originality' are also often connected with 'aesthetics'. A style or fashion refers to designs which possess a few recognisable common characteristics (e.g. Art Deco), while taste refers to personal preferences, sensitivity or appreciation of certain type of beauty or style. Although the originality of style gives rise to the singular individuality of a design and often enhances its value, aesthetics does not necessarily imply originality or vice versa. The richness and fuzziness of language to describe aesthetics have made it difficult to relate them directly to shape or other design parameters, which are more well-defined and structured. Although it seems impossible to produce categories that cater for all tastes and styles, it is nevertheless feasible to identify classes that cover the essence of more commonly accepted aesthetic intents and leave out individualistic differences that are more extreme. In previous papers 2,11,14 , we have attempted to construct a systematic framework for understanding of aesthetic characteristics and for integration of aesthetic intents to design. A methodology based on the theory of information communication has been developed to provide a two-way process to explore how aesthetic responses are related to shape, and how this understanding can facilitate the design of aesthetically pleasing products, as well as the evaluation of alternative designs. It is envisaged that this framework will be used as a base for computer tool development to support design for aesthetics. In order to set the focus of this paper within proper context, a brief overview of this methodology will be given below. However, the readers are recommended to refer to our previous papers 2,11 for further details on the methodology. The success of this methodology relies on the ability to identify commonly accepted aesthetic characteristics, and to match these characteristics against basic characteristics of products which can be computable.

This paper aims to address this problem, by drawing on relevant knowledge from other fields on aesthetic appreciation and criticism as well as established principles for achieving aesthetic products in various disciplines such as drawing, painting, sculpture and graphic design, where aesthetic consideration is a major issue. Throughout this paper, we use the term `product' to mean `designed product' in most cases, but also loosely to mean `art work or art object' when referring to other artistic disciplines. Section 2 covers briefly our methodology for understanding and design for aesthetics which had been dealt with in detail in two previous papers 2,11. Section 3 discusses commonly-used language for aesthetics and principles for producing aesthetic products, and how they can be used for investigating the interactions between aesthetic characteristics and basic characteristics of products. Section 4 identifies design variables in terms of shape, composition and physical properties, which exert most influence over aesthetic properties of the product according to these principles. It is envisaged that this knowledge would lead to a framework for systematically exploring aesthetic evaluation of alternative products, and to facilitate design for aesthetics.

II. A METHODOLOGY FOR COMPUTER-SUPPORTED DESIGN FOR AESTHETICS

We shall deploy three basic characteristics that influences the aesthetic of a product: shape, composition and physical attributes, as discussed in our previous work 11 . Other high-level characteristics such as style, fashion or taste may be expressed in terms of these three basic characteristics 3 . Shape may be viewed as a higher level than geometry and form, where geometry gives the lowest level explicit description of a 3D point set in space and form provides a more global description of a geometry. Composition is concerned with the arrangement and relative proportion of different parts of an object, while physical attributes include properties such as colour, texture, lighting and material. Our methodology for design for aesthetics is analogous to a model for communication of information. While semantic content of information is carried out by digital or analogue signals, the meaning of aesthetics is conveyed by shape, composition and physical attributes. In order to provide computer supported tools for design for aesthetic, we need to first understand how aesthetics relates to these basic characteristics of products, and then use this knowledge to construct tools to assist designers to communicate their aesthetic intents through the manipulation of shape, composition and physical attributes. This two-way communication process which consists of an exploratory and a creative loop, is illustrated in Figure 1. Each loop consists of four levels: statistical, syntactical, semantical and pragmatic. In order to carry out the exploratory loop, we need to have a systematic approach to perform experiments with objects (or designed products). In other words, product charateristics cannot be explored in a random fashion, but in a selective way by considering only those that can influence aesthetic characteristics directly in some way. We aim to achieve this by extracting relevant knowledge from the fields of philosophy of aesthetics and different disciplines in visual arts.

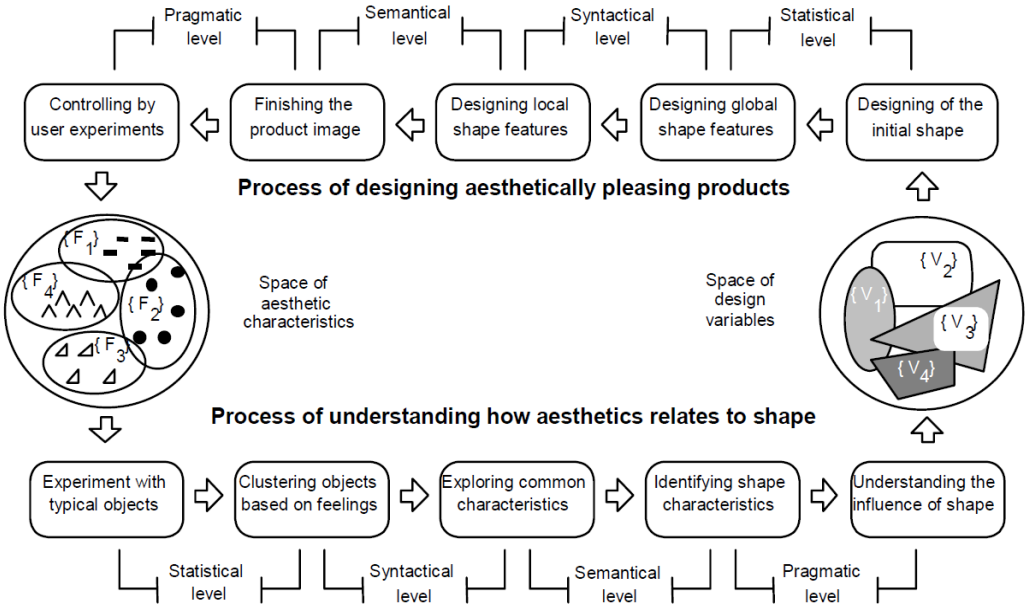

Figure 1. Two-way process for understanding and design for aesthetics

III. LANGUAGE AND PRINCIPLES IN AESTHETICS

Although the concept of aesthetics has been analysed in many studies of philosophy and psychology for over three hundred years, the focus was mainly on music, painting, drawing and literary work 1,5,,7,9,18,19,21. Very little attempts were concerned with critical analysis of aesthetics in design 15,16, or the inter-relationship between aesthetics and product characteristics. Psychological studies tended to focus on emotions and feelings 6, while market surveys attempted to model subjective judgements and responses in order to explain and predict customers' behaviour. However, these surveys are often performed on specific concept sketches or product prototypes for comparative emotional responses in order in order to select a design for a particular product 4. In a few cases where the intention was to draw some conclusion on the interplay of shape characteristics and emotions, only a small number of responses which are viewed as of interest for that particular line of products, are specially chosen for analysis. What needed is a systematic framework within which a comprehensive set of commonly accepted aesthetic variables and their corresponding product characteristics (e.g. shape parameters) can be determined and deployed to evaluate aesthetic quality of alternative designs and to facilitate design for aesthetics. We aim to construct this framework based on guidelines for aesthetic evaluation and established principles for achieving aesthetic work in various disciplines such as drawing, painting, sculpture and design 17,19,23,24. To this end, we first need to perform the following tasks:

• Identifying aesthetic properties and language terms that are commonly used for expressing aesthetic quality, and for aesthetic evaluation and criticism;
• Identifying principles for achieving aesthetic products and how these principles affect aesthetic properties;
• Analysing how characteristics of a product can be manipulated in order to achieve these principles.

The results of these tasks will provide us with clear guidelines for aesthetic evaluation of alternative designs as well as for facilitating design for aesthetics.

3.1. Aesthetic Language and Evaluation

Beardsley 1 who viewed aesthetics as a philosophy of criticism, gave a thorough analysis of aesthetic objects in literature, visual arts and music, and discussed the nature of critical evaluation of aesthetics. Since then, many philosophers have attempted to formalise the properties and meanings of aesthetics for evaluative purposes. In particular, Goldman 8 proposed a classification of evaluative aesthetic terms into the following eight categories:

• Broadly evaluative, e.g. beautiful, ugly, sublime, dreary.
• Formal, e.g. balanced, graceful, concise.
• Emotional, e.g. sad, angry, joyful, serene.
• Evocative, e.g. powerful, stirring, amusing, hilarious, boring.
• Behavioural, e.g. sluggish, bouncy, jaunty.
• Representational, e.g. realistic, distorted, artificial.
• Perceptual, e.g. vivid, dull, flashy.
• Historical, e.g. derivative, original, conservative.

These terms which have been used for art criticism and evaluation, describe clearly the typical reactions of an observer to a product. The categories are also useful for articulating the essence of what aesthetic terms convey. What seems to be more elusive is the relationship between these terms and the characteristics of the products in question. Another aspect that is relevant to our work concerns with what critics use for aesthetic evaluation of a product. It has been commonly accepted by many researchers in this field of philosophy that there are three basic aesthetic properties that could be used for evaluation: expression, representation and form. An art work (or a design) is expressive if it arouses some emotion from an observer. This emotion may be embedded in the work by an artist (or a designer) on purpose or unintentionally. Representation refers to the content of the art work, which may be actual, idealised or imagined, while form refers to the structure, organisation and composition of an object. It is worthwhile to note that the meaning of the term `form' within this context varies slightly with that discussed in Section 2. Stiny & Gips 20 later proposed another category called transparency which refers to cases where the reactions to art works depend on not only their representations, but also on what the representations may evoke via association with other elements such as emotions, experiences or ideas. For our purpose of providing computer support for design for aesthetics, it does not seem feasible to consider `transparency' due to the complexity of issues involved. On the other hand, other three aesthetic properties (expression, representation and form) can be adequately covered by the three basic characteristics of products - shape, composition and physical properties – that we have chosen to work with. It would therefore be more practical, in the first instance, to concentrate our investigation on how these three basic characteristics of a product influence the appreciation of its aesthetics, and to leave out other more complex aspects. To date, the only attempt to formalise aesthetics in a manner suitable for automation was by Stiny & Gips 20 whoprovided a general framework for constructing computer algorithms for aesthetic criticism and

design. These algorithms did not attempt to give a complete specification for evaluating or creating a specific art work, but offered a common structure to investigate important issues in aesthetics in a unified and coherent manner. However, apart from some simple examples which involved shape grammar and coloring rules for two-dimensional pictures, these algorithms still only gave very high level details and are not suitable for our purposes.

3.2. Basic Principles for Producing Aesthetic Products

A survey of literature in various disciplines such as drawing, painting, sculpture, industrial design and graphic design has revealed that there is much overlap in individual sets of basic principles for producing aesthetic products. Minor differences in meaning of a certain principle or omission of certain principles tend to be due only to the nature of media or material from which products are constructed. Furthermore, these principles when applied to products, provoke a diverse range of emotion responses which may be expressed in evaluative aesthetic terms mentioned in the previous Section. By judicious examination of such principles from these fields, we have come up with a list of nine principles that we believe, is sufficiently comprehensive to be used as a base for analysing the interactions between aesthetic characteristics and product characteristics. We now discuss the implication of each principle and how it relates to shape, composition and physical properties.

Balance

This principle is concerned with the effect of visual equilibrium. A design is monotonous and unexciting if evenness is strongly perceived in every characteristics, hence symmetric is generally avoided. On the other hand, asymmetry in shape features, colour, tone, size or arrangements of parts can give a design a more distinct characteristics. A balanced composition which, according to Ruskin, "puts several things together so as to make one thing of them", hence also creates unity. A closely related principle to balance is that of harmony where pleasant effects are created by grouping objects with characteristics which are in accordance with each other, e.g. complementary shapes and colours.

Proportion

Although the principle of proportion is closely related to that of balance, it tends to be dealt with separately to refer specifically to spatial balance. There are three types of proportions: linear, areal and volumetric. Linear proportion refers to the relation between the dimensions (e.g. length, width) of a single object (or feature), or between a linear dimension of one object (or feature) and that of another. A number of standard good proportion exist (e.g. the golden section). Areal and volumetric refers to similar relations in the areas and volumes of objects (or features). Within this context, distinct objects (or features) may be viewed as being separated by shape, colour, texture or material.

Dominance / Principality

This principle expresses that the unity of a design can be achieved by allowing one feature to dominate the rest. The dominant feature may be a distinct shape, colour, material or a distinct arrangement that mark it out from other features. It also creates a focal point which induces the effect of leading the eye towards it.

Alternation / Interchange / Contrast

The combination of things of significantly different characteristics create more impact, for example, light against dark, positive against negative shapes, smooth against sharp curvature, vertical against horizontal directions. However, great contrast in tone may prevent full appreciation of colour, by given an illusion of a different hue. For example, a colour would appear darker if surrounded by a much lighter colour.

Gradation / Continuity

Changes in a gradual or orderly fashion can add interest yet calm feeling, e.g. subtle variation in colours, shapes or the way features or object components are arranged. On the other hand, abruptness or discontinuity produces striking effects and unsettling feeling.

Solidity / Structural Coherence

The sensation of solidity can be created by fullness or robust characteristics such as round objects of heavy material and solid colours. Double curved surfaces generally give an impression of more fullness than a single curved surface. Abrupt transitions between parts tend to give a feel of being breakable or fragile. Visual power which suggests stability and strength, can also be increased by combining several elements of similar characteristics into one whole mass, e.g. a tight arrangement of sharp objects along a parallel direction.

Simplicity

Over-crowded features or over-precisely arrangement of objects may lose spontaneity and dilute focus.

Dynamics

Boldness in terms of energy and tension may be suggested by certain characteristics such as radial directions, gravitational pulling forces and outwardly thrusting forces. A sense of movement may also be induced by a definite orientation or path, e.g. a spiral composition around an axis.

Rhythm

The eye recognises a repeated form, colour, intensity or tone very quickly, hence repetitions can provoke interesting effects. However, some variations are needed to prevent monotony. A sensation of rhythm or visual kinetics can be created by the repetition of objects of similar characteristics, e.g. a group of cylinders of different sizes along a slanted and parallel direction induces a sensation of undulating rhythm.

IV. LINKING DESIGN VARIABLES TO AESTHETIC PROPERTIES

To provide concrete guidelines on how to carry out experiments described in Section 2 on alternative designs, we need to construct a scheme by which aesthetic judgements and responses may be evaluated systematically. For each principle for achieving aesthetic product, we identify concrete and computable properties of products that may be varied so that different degree of fulfilment of that particular aesthetic principle is achieved. This in turn would induce different responses which can be expressed in a range of aesthetic evaluative terms. The list of design variables in shape, composition and physical properties that link with nine principles is given in the following table.

Aesthetic Principles	Shape	Composition	Physical Properties Colour / intensity
Balance	• degree of asymmetry about centre of mass, major axes, and planes of reference (frontal, profile, median) • comparative size and spacing of features	• degree of symmetry of arrangements of objects about centre of mass, major axes and planes of references of the whole product	relative location, area coverage and variations of • complementary and opponent colours • different luminance intensity, hue, or saturation
Proportion	• ratio of major linear dimensions of object features • ratio of areas • ratio of volumes	• relative spacings of objects • relative size, area and volume of objects	not applicable
Dominance	• major orientation • smoothness of curvature • convexity of shape • global shape characteristics of smallest convex polygonal enclosing object • surface types: plane, single curved, double curved, warped	presence of distinct patterns of arrangements • orientation • path • grouping pattern (number of objects, positions within a group), e.g. triangular, pyramid, radiation, circular	presence of • prevalent colour • distinct colour • highlight (can work with hue, saturation and value separately or with their combination in terms of colour)
Alternation	• size • convexity • curvature • orientation	• size • convexity • curvature • orientation	• opponent colours • light / dark intensity
Gradation	• size • convexity • curvature • orientation	• size • convexity • curvature • orientation	• value • hue • saturation
Solidity	• convexity • surface types: double vs. single-curved • roundness • squareness	• tightness of arrangements • arrangement of similar objects • no hole, or a small	• saturation of colours • strength of intensity

	• smoothness of transitions between parts	number of holes	
Simplicity	• number of features • range of sizes • number of different line or curve orientations	• number of objects • number of different major line or curve orientations	• number of different colours or tones
Dynamics	• change of curvature, orientation of lines, planes towards (or away from) one point or along a specific orientation	• arrangement of objects towards one point (or away from) or along a specific path	• gradual change in hue, saturation or value of colours towards (or away from) one point or along a specific path • arrangement of similar colours towards (or away from) one point or along a specific path
Rhythm	repetitions of • orientation • line, curve types • volume size and global characteristics	repetitions of similar objects	repetitions of similar colours (in hue, saturation or value)

Our intention is to make sure that a variety of aesthetic judgements and emotional responses are obtained not at random, but in a more controlled and exhaustive manner which exert the most impacts. Furthermore, the combined effects of different aesthetic principles can also be explored using this method. To simplify the explanation on physical properties, we chooseto deal only with a few aspects relating to colour and tone. However, similar reasoning can be easily applied to other physical properties such as texture and material. One thing worth noting is that there is an inherent limitation on the extent to which aesthetic quality can be evaluated by examining variations in individual characteristics of a product because the expressive character of a volume is perceived not only as a combination of its features such as edges, planes and surfaces, but also as a whole entity. Despite this limitation, we believe that this systematic framework will add much useful knowledge towards computer supported design for aesthetics in a number of ways. By manipulating the identified design variables in terms of shape, composition and physical properties of a a given designed product, aesthetic judgements and responses can be explored. Similarly, aesthetic evaluation of alternative designs can be achieved by comparing the values of these variables for each design to see how well it has fulfilled each principle. In other words, evaluation being carried out this way, resembles that performed by professional critics. These variables can also be manipulated in the finishing stage when an initial design is checked and further refined to improve its aesthetic appearance.

V. CONCLUSION

We have shown how knowledge from various fields concerning with different aspects of aesthetics, can be integrated in order to construct a systematic framework to link design variables in terms of shape, composition and physical properties to aesthetic properties, judgements and responses. It is hoped that this analysis would make a concrete step towards providing computer-supported tools for design for aesthetics which has been up to now rather elusive.

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