Form language and style description

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This paper presents a 'style description framework' for the analysis of style as it is exhibited by objects, artifacts and, particularly, products. The framework equips a designer with both the ability to analyse existing styles and to describe new styles for target markets. A 'style profile' consists of a set of polar adjective scales and associated weighting mechanisms. Within the profile, stylistic attributes — in the form of values given on the scales — are grouped into six categories: form elements, joining relationships, detail treatments, materials, colour treatments and textures. Two weighting mechanisms, an importance index and confidence factor, fine-tune the description. The style profile can be used not only to communicate styles between designers and computers, but also to accumulate formal style knowledge. © 1997 Elsevier Science Ltd.

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All man-made environments and artifacts have styles — no matter what their creator’s intention — because formal, visual styles are created by particular sets of the formal elements that are also the constituent components of all visible forms. Designers, as designated ‘form-givers’, are expected to understand the workings of this process and to use this knowledge to give sensitive, intentional style to the artifacts they design.

Doblin\(^1\) expresses the belief that high level discriminators (designers, e.g. Gropius, Moholy-Nagy, Mies van der Rohe, Eames, Vignelli, Chermayeff, Rand, Nizzoli, Bill, Rams, etc.) have the ability to both recognize styles and think in systems. This suggests that the experience and expertise required to create styles and discriminate taste are both accumulatable and extractable.

This paper (1) investigates the definitions and usage of styles in various fields to determine the essence of formal styles and (2) proposes a style

description framework capable of equipping the designer with both the ability to analyse existing styles and to describe new styles for target markets. Ultimately, this framework can also be used to communicate styles between designers and computers, and to accumulate formal style knowledge.

1 The essence of formal styles

Formal style is a key factor which differentiates consumer markets. Designers understand this and work to develop skill in handling the subtleties of formal styles. Style is a key subject for design and has been since design became a profession — the recent debate on nationalism vs globalism in industrial design is yet another manifestation of the continuing discussion. The intent of this research is to explore the nature of style with the object of developing style-describing tools that can help designers to differentiate styles consistently and accurately.

1.1 Definitions of style

The word 'style' is used widely (and freely) to describe dissimilar characteristics of a broad range of subjects. Not surprisingly, the latitude covered by its definitions is quite extensive. The space given to dictionary and thesaurus explanations of style is vast. Following are some extracts for evidence:

'De Quincey’s style is verbose and Hemingway’s is terse;
The wealthy couple really lives in style;
He handled the awkward situation with style;
Argyle socks are back in style. Last year’s style was too trendy for me;
Which style of writing paper do you prefer?;
She styled my hair in a pageboy;
He styles himself a revolutionary.'

In academia, definitions of style also take many forms among different fields. Especially in the field of literature, the definitions are abundant and divergent. Enkvist thoroughly examines six different approaches to the definition of style:

'... style as a shell surrounding a pre-existing core of thought or expression; as the choice between alternative expressions; as a set of individual characteristics; as deviations from a norm; as a set of collective characteristics; and as those relations among linguistic entities that are statable in terms of wider spans of text than the sentence.'

In the field of literature, literary historians and critics try to separate stylistic features from nonstylistic ones based on whether these features associate a work with one rather than another artist, period, region, school, etc. As Goodman explains ‘Stylistics ... is confined to features of what and how


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the works symbolise, and still further to such of these features as are characteristic of a given author, period, region, school, etc." Echoing this, Beardsley suggests that:

'No feature of any work is a stylistic feature of that work unless it belongs to a class or family of features that marks that work as having, or being in, a style — that is, as belonging to a group of works identified as a group by that class or family of features.'

Historians and critics view style differently, exchanging each others' ends and means. While the historians use their understanding of style to identify a painting as Rembrandt's or a poem as Hopkins', the critics use the identification of authorship as a means toward discriminating the Rembrandt properties or the Hopkins properties of the work.

In the field of linguistics, definitions of style focus on the unique combination, as well as the frequency distribution of certain linguistic elements, including expressive and evocative ones. Enkvist, emphasizing the latter, suggests 'The style of a text is the aggregate of the contextual probabilities of its linguistic items.' Cooper, alternatively, argues for both the uniqueness and objectiveness of style and states that: 'Style is the mode of representation in language, conditioned partly by the psychological peculiarities of the one who represents, partly by the matter and purpose of what is represented.'

In the field of musicology, 'free choices' and 'replicated features' are the two most salient characteristics of style. The definition by Meyer proposes that: 'Style is a replication of patterning, whether in human behaviour or in the artifacts produced by human behaviour, that results from a series of choices made within some set of constraints.' The concept of style in this definition has been extended beyond man-made artifacts to cover human behaviour.

In the visual arts, style for art historians focuses on the classification or arrangement of a variety of works of art. As Feldman defines it: '... an art style is a grouping or classification of works of art (by time, region, appearance, technique, subject matter, and so on) which makes further study and analysis possible.' For others, the notion of style is rather a notion about a set of visual characteristics; as Schapiro defines it: 'By style is meant the constant form — and sometimes the constant elements, qualities, and expression — in the art of an individual or a group.' Ackerman writes in a similar way:

'... the study of the arts, works — not institutions or people — are the primary data; in them we must find certain characteristics that are more or less stable,... and flexible.... A distinguishable ensemble of such characteristics we call a style.'
For architects, Saarinen provides a compact, succinct definition: ‘By style we mean a form language.’\textsuperscript{14} For visual communications, Dondis says: ‘Style is the visual synthesis of the elements, techniques, syntax, inspiration, expression, and basic purpose.’\textsuperscript{15}

In the light of such abundant and divergent definitions, any single resolution well-fitted to the needs of design seems unlikely. However, the effort is valuable if just to obtain a definition congruent to the needs of the field.

Two approaches suggest themselves. The first applies the techniques of analysis, comparison and analogy to the given definitions. Unfortunately, an immediate difficulty is that the definitions are not only from different viewpoints, but also from different conceptual levels. The more the tools of analysis, comparison and analogy are applied, the more imperative is the need for an underlying structure upon which to organize the significance of the findings.

This ushers in the second approach, which views the problem in a more holistic, systemic way. Only after the functions, structure and components of styles are evident can the multitude of descriptions and definitions be apprehended clearly.

In conclusion, while the concept of style has been discussed and defined widely, in generality and in detail, the very breadth of the attention has obscured the result. It is time to redefine it once more, within the realm of design, to provide the means for more precise communication as a basis for new computer-supported design tools.

An efficient way to capture the overall form of an object is to examine it systemically. As Smith indicated bluntly: ‘... nothing can be understood without looking not only at it in isolation on its own level but also at both its internal structure and the external relationships which simultaneously establish the larger structure and modify the smaller one.’\textsuperscript{16} Following this very good advice, three levels of formal style will be explored systematically, i.e. functions, structure and components.

1.2 The functions of formal style
For a system, components are ‘what’ it consists of; structure is ‘how’ it is constructed; and functions are ‘what’ it is expected to do in or to the environment that accommodates it. There is also a subtle, but clear difference between the notion of function and that of performance. The latter refers to what a system did, while the former refers to what a system is expected to do. For natural living systems, no one can expect more from
an organism than what it was born to do; its functions are basically decided by its internal structures. For man-made systems such as artifacts or institutions, functions, in contrast, must be designed before internal structures can be developed. As the functions of an artifact or institution are external, they must be carefully analysed and defined before the system is implemented.

To avoid a problematic circular definition, the functions of formal styles should not be based upon their internal structure. A much better approach is to survey the field for conventional usage. Among others, Schapiro\(^{17}\) and Enkvist\(^{18}\) provide quite exhaustive coverage of the functions of style. From their lists, 'classifying', 'attributing', 'expressing' and 'stimulating' are the four most representative.

1.2.1 Classifying
The assumption this function is based upon is that '... every style is peculiar to a period of a culture and, ... in a given culture or epoch of culture, there is only one style or a limited range of styles.'\(^{19}\) A set of specific stylistic features can be associated with a specific time period in history, or with a specific place in geography to help classify or identify an individual style or group of styles. This is the function most commonly used by art historians, philosophers of history and literary historians. Schapiro\(^{20}\) points out that a systematic picture of the temporal and spatial distribution of styles throughout the globe has been constructed by scholars through the application of this function.

1.2.2 Attributing
Based on the same assumption as that assumed for classifying, but with looser confinement, a set of canonical stylistic features along with a style name, e.g. Cubism\(^{21}\), Shaker design\(^{22}\), etc. can be employed as recognizable cues (instead of strict rules) to give a work of art or design certain stylistic references. Most people, other than historians, tend to use the word style for this purpose.

1.2.3 Expressing
The most primary assumption of all is that style is independent from content; thus, various styles can be chosen to express the very same message without changing its meaning. Stylistic features can be freely chosen among alternatives to express the desired style. Linguists are major subscribers to this usage. Based on the same assumption, but reversing the usage, several computer programs\(^{23}\) have been developed to help capture statistically the stylistic features expressed within a prose or poetry piece. These results are then used to identify or attribute that work to an individual...
or movement with similar style. A thorough discussion of expressiveness in style can be found in Ullmann’s *Language and style*.

### 1.2.4 Stimulating

Based essentially on the same assumption underpinning expressing, all stylistic traits can be decomposed into basic units. These can then be used to compose a desired unique style according to a set of predefined compositional rules — or can be used to generate a totally new style through heuristic or even random combinations or configurations. This usage is not new to the fields of visual art and design, but more sophisticated applications are found in the fields of music, and literary and linguistic stylistics.

In general, the functions being served in the various fields — with various minute adjustments to satisfy individual differences — fall into three basic categories: analysis, evaluation and synthesis. Through analysis, individual styles, group styles, period styles and universal styles can all be identified. Through evaluation, any work of art or design can be compared against normative characteristics to decide whether it is of a style or not. Through synthesis, existing styles can be extended and new styles created.

### 1.3 The structure of formal style

What the external appearance of an object displays is largely decided by its internal structure. Style, as a concept rather than object, can also be viewed this way. Smith states: ‘Style is the recognition of a quality shared among many things; the quality, however, lies in structure on a smaller scale than that of the things possessing the quality.’ He continues, ‘Everything involves structural hierarchy, an alternation of external and internal, homogeneity and heterogeneity.’ Style is no exception; it too is hierarchical; e.g. it is not difficult to place a Braun coffee maker within a framework of European style, German style or even Braun style. The notion of hierarchy in the process of making such differentiations is implicitly demonstrated. In this case, European, German and Braun represent three different levels in a style hierarchy. The discrimination could also be made more finely, even down to a specific period of work for a specific designer. By the same token, it could also be aggregated more coarsely to a universal 20th century western style, distinguishable from styles developed in other historic periods. Such hierarchical characteristics are routinely used in the field of art history as a means for classifying styles or schools of visual expression for easy identification or reference. Smith has an extensive discussion of the hierarchy of style.

Meyer suggests: ‘Styles, and the constraints governing them, are related to one another in hierarchic fashion.’ According to the nature of the con-

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27 Knight, T W *The generation of Hepplewhite-style chair-back designs* *Environment and Planning B Vo* Vol 7 (1980) 227-238
33 Meyer, L B *Toward a theory of style* in B Lang (ed) *The concept of style* University of Pennsylvania Press, Philadelphia (1979) 14
strains involved, Meyer divides this hierarchy into three large classes: Laws, Rules, and Strategies, each of which is, in turn, divided into various subclasses. Ullmann builds a similar structure identifying three distinct levels of stylistic analysis: (1) stylistics of the sound, (2) stylistics of the word, and (3) stylistics of the sentence. Both authors espouse the notion of hierarchy and make use of it successfully in analysing styles.

Components and composition more often than not exist in pairs, frequently expressing cause-and-effect. Which is the cause and which the effect between component and composition is not of consequence here; what is important is their coexistence. It is almost impossible for an object to have the one without the other. For style to have both components and composition means that there must be multiple, distinguishable elements, often referred to as 'stylistic elements'. People tell one product from another by the manner in which component parts are shaped, coloured, textured and put together. As a concept for attributing objects, style composes as many components as needed to describe the object in question. One style cannot be differentiated from others if there are no different components and no distinguishable change(s) in relationships among them.

Dondis regards visual elements, techniques, syntax, inspiration, expression and basic purpose all as components of style from the point of view of style synthesis. Smith suggests that differences in styles arise from changes or differences in constituent elements and relationships among them. He makes an ingenious analogy between style and chemical phase from the point of view of style identification:

'Bulk properties of matter such as density, colour, conductivity, crystal structure, or vapour pressure by which a chemical phase is identified are not a property of any of the parts (though they would not exist without them) but rather are external characteristics depending on the pattern of interaction between the atomic nuclei, electrons, and energy quanta and the extension of this pattern by repetition throughout the entire volume of the phase concerned. The pattern and the property both disappear when there are too few parts, and they change when an interface into another distinguishable phase is crossed. So with styles of art. They cannot be seen from insides, although the structure on which they depend can be. Some styles, like some phase (for example, liquid or solid solutions), can tolerate considerable diversity in the shape and constitution of their parts, while others (like simple molecules and covalent crystals depending upon the precise symmetry of nearest-neighbor interaction) are intolerant of substitution: if different parts are introduced, the whole structure will adjust to a new form. . . . In the aesthetic case the identifying uniformity corresponding to the physical-property test of a chemical phase is that of some psychological response triggered by the repetition of a detail of pattern or a color relationship.'
In order to analyse style structurally, Kubler[40] proposes a hexagonal conceptual framework. In this model, six components, in three pairs, create the phenomenon of style: craft and format corresponding to shape; signage and modus to meaning; and period and sequence to time.

Though each has a different definition of elements, all of these authors agree that a distinguishable combination or configuration of stylistic elements creates visual stylistic elements which create visual style. Styles are independent of subjects. The arguments by stylistic theorists and literary critics on whether style (form, manner) can be separated from subject (content, matter) can be roughly grouped into two distinct camps. Goodman[41], Cooper[42] and Enkvist[43], among others, argue that subject matter, if not decidedly, surely influences the styles expressing it. Ullmann[44], Hendricks[45] and Barthes[46], among others, suggest that style can be studied or analysed independently without being contextually confined to a specific subject.

From daily experience, however, we know that a design style not only can be shared among various objects, but also can coexist among different domains; e.g. ranging from such personal items as a hair dryer or watch, to such public facilities as telephone booths and trains, products can be recognized as having a single style, e.g. Bauhaus[47] or Memphis[48] design without much confusion or surprise to the casual viewer. Similarly, a building, a poem, a painting or a film can also share a single style, be it modern[49] or pop[50], without offending any established practices. All of this demonstrates the independence of styles.

From this understanding of the nature of style, the following statements about structure can be made: (1) Hierarchy: when people define, interpret or identify styles at different levels, the underlying hierarchy of style can help to rationalize the arguments; (2) Component and composition: at comparable levels, styles can easily be distinguished by the distinct combination or configuration of a set of components of interest; and (3) Independence: people can discuss a style or styles without relating it or them to specific objects or particular fields.

1.4 The components of formal style

Formal elements and stylistic features are the two major component classes of formal style. Before going further, the differences between them need to be clarified. Formal elements, equivalent to Dondis’s visual elements[51] and Bowman’s form vocabulary[52], are the basic substance of what we see; stylistic features represent those psychological qualities that we feel.
Chief among other treatises, Dondis's, Bowman's, Osgood's and Kojirō's are the foundation resources for the compilation of the components of formal style to be used here. These contributions will be reviewed in detail under the two classifications defined above.

### 1.4.1 Formal elements

The basic elements of a product that we can see include the solids constituting the product's body, any graphics on the surface, materials used in construction, colours and textures. These give physical properties to the object. A style can be expressed through a unique composition and configuration of these elements. Dondis suggests a list of 10 visual elements used in basic two-dimensional graphic design: dot, line, shape, direction, tone, colour, texture, dimension, scale and movement. Bowman limits his form vocabulary to five elements, point, line, shape, value and texture; others appear at higher levels of his pace grammar or perspective idiom. Other definitions of formal elements vary. In Pile's *Dictionary of 20th-century design*, 'The form of a thing involves its shape, color, texture, ornamentation, and every other aspect of its physical reality. . . . The term 'visual form' is also often used to help define the concept of form and limit it to the qualities of an object that can be seen.'

### 1.4.2 Stylistic features

The psychological attributes we use to describe a product are abundant, e.g. sharp or dull, heavy or light, balanced or unbalanced, smooth or rough, etc. Osgood et al. first utilized polar adjective pairs to measure the meaning of fuzzy words. These pairs can be further grouped into categories, e.g. valuation, potency, activity, etc. Dondis uses such pairs as balance-instability, symmetry-asymmetry, simplicity-complexity, etc. to describe qualities for visual communication. Also mentioned are three levels for expressing a visual message: representation, symbolism and abstraction. Again, these can be transformed into polar adjective pairs and used as stylistic features.

Conventionally, form is a term used to describe general shape, structure, design, appearance, type, etc. while style is used to describe the distinctive quality of a shape, structure, design, etc. In other words, only those objects which have distinctive qualities have style, while all objects have form regardless of whether they have style; a style needs a form to present its visible appearance. Even without one-to-one relationships, these two concepts — form and style — should be capable of being integrated within a framework constructed from formal elements and stylistic features.

Kojirō, taking history and climate into account, proposes a quite complex framework of this sort for attributing forms found in Japan. The system...
includes two axes representing time–space, or history–climate, respectively, and a tetrahedron with four vertices representing purpose, idea, material and hand. According to Kojiro’s explanation, purpose means the use for which the form is intended; idea means artistic volition, conception or inspiration to create form; material means the raw materials which constitute the substance of form; and hand means the technical skill or talent that creates form. All forms can be located within this tetrahedron based on their universal characteristics and can further be plotted onto the time–space co-ordinate system for a specific cultural reference.

2 A style description framework (SDF)

Building on the concepts of formal elements and stylistic features, a framework for style description can be created. The model uses polar adjective pairs, augmented by appropriate weighting mechanisms, as a means for the stylistic assessment of qualities exhibited by the elements of a product’s form. This framework enables a designer both to analyse and understand existing styles and to develop new styles especially suited to specific markets.

2.1 Structure of the Style Description Framework

2.1.1 Concept

In order to analyse and describe styles as objectively as possible, underlying visual elements, rather than general overall qualities, should be examined. To do this, a set of descriptive polar adjective pairs are employed in the style description framework.

In this model, the style description framework records salient attributes for a style of interest. For each salient attribute, there is one estimated centric value converted from the scale used for the polar adjective pair, one confidence factor adjusting the range of the centric value, and one importance index regulating the weight of the attribute for the style of interest. Both the technique for converting qualitative descriptions to quantitative values proposed in Chien’s⁶⁴ thesis and Lee’s⁶⁵ linguistic evaluation method using fuzzy set theory can be employed to calculate the position of a style or the distance between any two styles in the style space. More detailed discussion will be devoted to this in the next section.

2.1.2 Hierarchy

An object-oriented concept is adopted to construct a style hierarchy and make the instantiation of a new style easier. A style class with fewer salient attributes (meaning most importance indices have low values) and/or looser boundaries (meaning most confidence factors have low values) is likely to

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be at a higher level in the style hierarchy. A style subclass, on the other hand, will either have more salient attributes, thus becoming more specific in the entire style space, or will have stricter boundaries, meaning it is more specific regarding certain attributes than its parent class. Creating a new style class at any level can be done easily by instantiating from a parent class and then making the necessary adjustments to the estimated values and/or the values of the importance indices to give the new class its own character.

2.1.3 Realization

The proposed framework regards the entire style space as an $n$-dimensional space in which each dimension is represented by three attribute-value tuples $[a, ev], [a, cf]$, and $[a, ii]$, denoting $\langle$attribute, estimated-value$\rangle$, $\langle$attribute, confidence-factor$\rangle$ and $\langle$attribute, importance-index$\rangle$, respectively. In this space, any specific style of interest $s$, can always be represented as $S(s)$ with $n$ pairs of attribute-estimated-value, attribute-confidence-factor, and attribute-importance-index tuples:

$$S(s) \equiv \{s, \{ev, [a(1), ev(1)], [a(2), ev(2)], ...[a(n), ev(n)]\},$$

$$\{cf, [a(1), cf(1)], [a(2), cf(2)], ...[a(n), cf(n)]\},$$

$$\{ii, [a(1), ii(1)], [a(2), ii(2)], ...[a(n), ii(n)]\}\},$$

in which $s$ is the style’s name; and ev, cf and ii are the identifiers for the estimated value, confidence factor and importance index, respectively. This information is stored and accessed as an object. Since each estimated value, confidence factor and importance index is always associated with its corresponding attribute, the order in which they are saved in memory is of no significance, as long as they follow the right identifier. The same holds for the three sets of data ev, cf and ii, for each of them is always associated with its corresponding identifier.

The class and subclass relationship between any two styles $x$ and $y$ can be described as follows: let

$$S(x) = \{x, \{ev, [a(1), evx(1)], [a(2), evx(2)], ...[a(n), evx(n)]\},$$

$$\{cf, [a(1), cf(x)(1)], [a(2), cf(x)(2)], ...[a(n), cf(x)(n)]\},$$

$$\{ii, [a(1), iix(1)], [a(2), iix(2)], ...[a(n), iix(n)]\}\};$$

$$S(y) = \{y, \{ev, [a(1), evy(1)], [a(2), evy(2)], ...[a(n), evy(n)]\},$$

$$\{cf, [a(1), cf(y)(1)], [a(2), cf(y)(2)], ...[a(n), cf(y)(n)]\},$$

$$\{ii, [a(1), iiy(1)], [a(2), iiy(2)], ...[a(n), iiy(n)]\}\};$$

$x$ is a subclass of $y$, if and only if

(a) $|ii(x) - ii(y)| \leq Dy$, for $j = 1,n$;
(b) \( \{ U(j)(evx(j)*cfx(j)) \leq U(j) \leq (evx(j)*(2 - cfx(j))) \} \)
\( \subseteq \{ V(j)(evy(j)*cfy(j)) \leq V(j) \leq (evy(j)*(2 - cfy(j))) \} \) for \( j = 1, n; \)

where

1. \( D_y \) is the maximum deviation allowed for importance indices of \( y; \)
2. \( \{ U(j) \} \) and \( \{ V(j) \} \) are value intervals including end points for each \( j. \)

For better understanding, a simplified example with real values will illustrate this relationship. Let us say there are only four attributes (dimensions) in the style space, and they are: geometric–biomorphic (for form elements), monolithic–fragmentary (for joining relationships), functional–decorative (for detail treatments) and single–multiple (for materials). The estimated values of these four attributes for style \( y \) are: 0.2, 0.3, 0.1 and 0.3, respectively on a 0.0–1.0 scale, and are: 0.21, 0.32, 0.11 and 0.28 on the same scale for style \( x. \) The confidence factors are: 0.7, 0.6, 0.6 and 0.6, and 0.9, 0.8, 0.8 and 0.7 for styles \( y \) and \( x, \) respectively. The importance indices are: 0.5, 0.6, 0.7 and 0.3, and 0.6, 0.7, 0.6 and 0.4 for styles \( y \) and \( x, \) respectively; and the maximum deviation allowed for style \( y, D_y, \) is 0.15. Then, the test for class/subclass proceeds:

\[ |iix(1) - iiy(1)| = |0.6 - 0.5| = 0.1 \leq 0.15; \]

\[ |iix(2) - iiy(2)| = |0.7 - 0.6| = 0.1 \leq 0.15; \]

\[ |iix(3) - iiy(3)| = |0.6 - 0.7| = 0.1 \leq 0.15; \]

\[ |iix(4) - iiy(4)| = |0.4 - 0.3| = 0.1 \leq 0.15; \]

and

\[ \{ U(1)(evx(1)*cfx(1)) \leq U(1) \leq (evx(1)*(2 - cfx(1))) \} \]
\[ = \{ U(1)(0.21*0.9) \leq U(1) \leq (0.21*(2 - 0.9)) \} \]
\[ = \{ U(1)|0.189 \leq U(1) \leq 0.231 \} \]
\[ \subseteq \{ V(1)(evy(1)*cfy(1)) \leq V(1) \leq (evy(1)*(2 - cfy(1))) \} \]
\[ = \{ V(1)(0.2*0.7) \leq V(1) \leq (0.2*(2 - 0.7)) \} \]
\[ = \{ V(1)|0.14 \leq V(1) \leq 0.26 \}; \]
\{U(2)|\text{evx}(2) \times \text{cfx}(2) \leq U(2) \leq (\text{evx}(2) \times (2 - \text{cfx}(2)))\}
= \{U(2)|0.32 \times 0.8 \leq U(2) \leq (0.32 \times (2 - 0.8))\}
= \{U(2)|0.256 \leq U(2) \leq 0.384\}
\subseteq \{U(2)|\text{evx}(2) \times \text{cfx}(2) \leq U(2) \leq (\text{evx}(2) \times (2 - \text{cfx}(2)))\}
= \{U(2)|0.3 \times 0.6 \leq U(2) \leq (0.3 \times (2 - 0.6))\}
= \{U(2)|0.18 \leq U(2) \leq 0.42\};

\{U(3)|\text{evx}(3) \times \text{cfx}(3) \leq U(3) \leq (\text{evx}(3) \times (2 - \text{cfx}(3)))\}
= \{U(3)|0.11 \times 0.8 \leq U(3) \leq (0.11 \times (2 - 0.8))\}
= \{U(3)|0.088 \leq U(3) \leq 0.132\}
\subseteq \{U(3)|\text{evx}(3) \times \text{cfx}(3) \leq U(3) \leq (\text{evx}(3) \times (2 - \text{cfx}(3)))\}
= \{U(3)|0.1 \times 0.6 \leq U(3) \leq (0.1 \times (2 - 0.6))\}
= \{U(3)|0.06 \leq U(3) \leq 0.14\};

\{U(4)|\text{evx}(4) \times \text{cfx}(4) \leq U(4) \leq (\text{evx}(4) \times (2 - \text{cfx}(4)))\}
= \{U(4)|0.28 \times 0.7 \leq U(4) \leq (0.28 \times (2 - 0.7))\}
= \{U(4)|0.256 \leq U(4) \leq 0.384\}
\subseteq \{U(4)|\text{evx}(4) \times \text{cfx}(4) \leq U(4) \leq (\text{evx}(4) \times (2 - \text{cfx}(4)))\}
= \{U(4)|0.3 \times 0.6 \leq U(4) \leq (0.3 \times (2 - 0.6))\}
= \{U(4)|0.18 \leq U(4) \leq 0.42\}.

From the calculation, style x is a subclass of style y according to the definition of class–subclass relationship. Figure 1 shows the class–subclass relationship between subclass x and its parent class y using their profiles.

2.1.4 Adaptation
The proposed framework is based on an open structure and is, therefore, highly adaptive. As the structure is flexible, a new style can easily be configured by assigning a new set of evs, cfs, and isis to a set of existing attributes. Moreover, because the structure is open, new attributes can be added to the attribute list whenever necessary.

![Figure 1 A schematic diagram showing the relationship between subclass Sx and its parent class Sy](image)

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2.2 The Style Profile

The Style Profile collects detailed attribute information in a format that allows comparison visually. Figure 2 shows an example of a Style Profile.

2.2.1 The major groupings

The major factors contributing to the formation of visual styles can be summarized as: form elements, joining relationships, detail treatments, materials, colour treatments and textures — six categories. The attributes adopted for describing styles can be assigned to these six categories correspondingly. They are:

1. Form elements — including the number of different form elements used, the shape(s) of the form elements used and the symbolic associations;
2. Joining relationships — including the number of different spatial relationships used, spatial relationships, number of different joining types used and joining type(s);
3. Detail treatments — including the number of different treatments used on faces, edges and corners, and the treatments used on faces, edges and corners;
4. Materials — including the number of different materials used, type(s) of materials used and the finishing of the materials;
5. Colour treatments — including the number of different colours used, colours used and tone groups (colour images); and
6. Textures — including the number of textures used, type(s) of textural patterns, characteristics of textures and tactility of textures. The first

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<th>Estimated Value</th>
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Figure 2 The complete form of the style profile
three groups decide the geometric modelling of the object; the second
three groups control the surface mapping.

2.2.2 The Polar adjective pairs
Polar adjective pairs are the core constituents of the Style Profile. To obtain
descriptive values, each attribute is associated with one pair of polar adjectives. These polar adjective pairs are organized according to the six
major groupings:

2.2.2.1 Form elements.
Seven polar adjective pairs are included to describe the form elements
representing distinguishable parts of an object:

- Harmonious–contrasting: do the form elements match well or contrast
  with each other?
- Homogeneous–heterogeneous: are the form elements of one kind or of
  several different types? If more than one kind of form elements exists,
  there will be more than one estimated value for each of the following
  attributes to accommodate the coexistence of multiple characteristics.
- Geometric–biomorphic: are the form elements geometric, biomorphic
  or partially biomorphic?
- Pure–impure: are the form elements pure in appearance or impure?
- Simple–complex: do the form elements demonstrate the quality of sim-
  plicity or not?
- Balanced–unstable: are the form elements in a balanced state or an
  unstable one?
- Low cultural reference–high cultural reference: do the form elements
  have any cultural association?

2.2.2.2 Joining relationships.
Polar adjective pairs are used here to describe the joining relationships
among parts in three dimensions.

- Monolithic–fragmentary: do the joinings make the object look like a
  single piece or one that is fragmentary?
- Self evident–hidden: are the joinings clearly visible or very subtle?
- Static–dynamic: does the construction of form elements result in a
  structure that seems static or one that seems dynamic?

2.2.2.3 Detail treatments.
Four adjective pairs describe the detail treatments given an object.

- Uniform–multiform: do the detail treatments given the object demon-
  strate the quality of homogeneity or heterogeneity? If more than one
type of detail treatments exists, there will be more than one estimated value for each of the following attributes to accommodate the multiple characteristics.

- Angular-rounded: how are the details of the object perceived? Sharp-cornered? Or soft and rounded?
- Functional-decorative: do the details look practical or merely ornamental?
- Subtle-bold: are the details very refined or very striking?

2.2.2.4 Materials.
Four polar adjective pairs characterize the materials used in an object.

- Harmonious-contrasting: do the materials used match each other well? or do they create a strong contrast?
- Single-multiple: how many different types of materials are used in the object; just one or quite a few? If there is more than one type of material, there will be more than one estimated value for the hard-soft and matte-glossy attributes to express their multiple characteristics.
- Hard-soft: do the materials used contribute to a feeling of hardness or softness?
- Matte-glossy: do the materials used create a dimmed or shiny finish?

2.2.2.5 Colour treatments.
Four pairs of polar adjectives similar to those for materials are employed to portray colour treatments.

- Harmonious-contrasting: do the colours used match each other well? Or do they create a strong contrast?
- Single-multiple: How many different hues appear in an object? Just one or quite a few? If more than one colour appears, there will be more than one estimated value for cool-warm and hard-soft attributes to express the multiple colour images.
- Cool-warm: do the colours used suggest a cool or warm image?
- Hard-soft: do the colours used create a hard or soft image?

2.2.2.6 Textures.
Five adjective pairs are used to differentiate the textural patterns exhibited on an object.

- Harmonious-contrasting: do the textural patterns used match each other well or do they create a strong contrast?
- Single-multiple: how many different textural patterns appear on the object, just one or many? If more than one textural pattern appears,
there will be more than one estimated value for each of the following attributes to express the multiple characteristics.

- Subtle-bold: are the textural patterns fine-grained or coarse?
- Regular-irregular: are the textural patterns well-regulated and predictable, or asymmetric and erratic?
- Tactile (3D)-visual (2D): are the textural patterns three dimensional or two dimensional?

2.2.2.7 The refinement mechanisms.

Two weighting factors are used to refine the Style Profile: an importance index and confidence factor. Two polar adjective pairs, i.e. insignificant-significant and uncertain-certain, are designated to importance indices and confidence factors, respectively. The former indicates how significant an attribute is to a specific style — similar styles should have similar importance index values for corresponding attributes (i.e. the importance index profiles of two similar styles should resemble each other). Figure 3 shows two profiles of importance indices from two similar styles. The latter adjective pair, uncertain-certain, denotes how certain the estimated value is, or how much a product can deviate from the estimated value and still be considered as ‘of this style’. The higher this measure, the higher the certainty and the lower the deviation.

Two fuzzifiers, ‘roughly’ and ‘barely’, defined in Lee’s thesis, can be used to indicate when the information that the estimated value is based upon is insufficient or scarce, respectively. Chien defined a seven-layer ‘attractor’ that can also be used to convey more refined confidence.

Form Elements  
Harmonious - Contrasting  
Homogeneous - Heterogeneous  
Geometric - Biomorphic  
Pure - Impure  
Simple - Complex  
Balanced - Unstable  
Low - High Cultural Reference  
Monolithic - Fragmentary  
Self Evident - Hidden  
Static - Dynamic  
Angular - Rounded  
Functional - Decorative  
Subtle - Bold  
Harmonious - Contrasting  
Single - Multiple  
Hard - Soft  
Mat - Glossy  
Harmonious - Contrast  
Single - Multiple  
Cool - Warm  
Hard - Soft  
Harmonious - Contrasting  
Single - Multiple  
Subtle - Bold  
Regular - Irregular  
Tactile (3D) - Visual (2D)  

Figure 3 Profiles of importance indices of two similar styles  

Form language and style description  

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2.2.2.8 The Scoring System.

Along with an adjective pair, a five-rank descriptive scale is used for describing each attribute. Taking the cool–warm pair as an example, these five ranks are: very cool, cool, neutral (hard to tell), warm and very warm. The five fuzzy descriptors are mapped to a normalized scale, 0.0–1.0, with the first descriptor close to value 0.0 and last near the value 1.0 (in the case of cool–warm, very cool produces a value close to 0.0, while very warm is near 1.0). A more detailed discussion of fuzzy set theory and linguistic variables can be found in Lee's thesis.

As described earlier, a style class \( s \) is represented as:

\[
S(s) = \{ s, [ev,[a(1),ev(1)),[a(2),ev(2)],...[a(n),ev(n)]},
\[cf,[a(1),cf(1)),[a(2),cf(2)],...[a(n),cf(n)]},
\[ii,[a(1),ii(1)),[a(2),ii(2)],...[a(n),ii(n)]} \},
\]

As an instance, a product \( p \) can be described as:

\[
S(p) = \{ p, [ev,[a(1),ev(1)),[a(2),ev(2)],...[a(n),ev(n)]},
\[cf,[a(1),cf(1)),[a(2),cf(2)],...[a(n),cf(n)]},
\]

As a product must be evaluated with estimated values and confidence factors for each attribute before being given any particular style label, importance indices are left out in the above description. The location of any given style or product \( p \) in a style space of \( n \) dimensions can then be represented by \( L(p) \) as:

\[
L(p) = \{ p, [a(1),ev(1)),[a(2),ev(2)],...[a(n),ev(n)]} \]

where \( p \) is the name identifier of the product or style.

The image distance between two products, or styles \( x \) and \( y \), called the absolute distance \( D(x,y) \), can be calculated as:

\[
D(x,y) = \sqrt{\sum_{j=1}^{n} (evy(j) - evx(j))^2};
\]

and the image distance from a product, or a style \( p \) to a specific style \( x \), called the referential distance \( Dr(x,p) \), can be calculated as:

\[
Dr(x,p) = \sqrt{\sum_{j=1}^{n} ii(x,j)(evp(j) - evx(j))^2 / \sum_{j=1}^{n} ii(x,j)}
\]
For the referential distance, the importance index of each attribute of the referential style \( x \) is used to weight each corresponding estimated value, while in calculating absolute distances, no importance indices are necessary.

Several issues need to be addressed before leaving the notions of class–subclass, absolute and referential distances. As the definition has been given, two styles with a class–subclass relationship will not necessarily have smaller absolute or referential distances between them than exist between others without such a relationship. This is possible because the class–subclass relationship takes into account the confidence factors, while the absolute and referential distances do not. The situation might occur, e.g. that two styles, such as the German and Braun\(^69\) styles, with a distant class–subclass relationship, might end up having greater image distance between them than two styles, e.g. the Braun and Krups\(^70\) styles, that do not have a class–subclass relationship. The referential distance from a product or a style to any particular style may also be less (or more) than that to another style even though the two styles referenced may have exactly the same estimated values on all the attributes — because the importance indices for the attributes of the referenced styles may not be the same.

The fact that two styles have a small absolute distance between them does not mean that they will have a small referential distance, either. This seeming discrepancy is possible because the referential distance differentiates the importance indices of the attributes of the referential styles, while the absolute distance takes no consideration of the importance indices. This situation resembles that where two styles with a small absolute distance between them might end up having much larger referential distance between them than two others with a greater absolute distance. An illustration is the case where Braun products are closer to the functionalist style than the minimalist style in absolute distance (without the weighting of importance indices), but better qualified as the minimalist style than the functionalist style in referential distance (with the weighting of importance indices). In general, however, the smaller the absolute distance is between two styles, the closer will be their image.

2.3 Some testing examples

Figure 4 shows products of Bauhaus and Memphis styles. The Bauhaus style is also frequently used as the representative of modernism, or the German style, while the Memphis style epitomizes post-modernism, or the Italian style. Figures 5 and 6 are the two Style Profiles for the products shown in Figure 4, representing the Bauhaus and Memphis styles, respectively. Figure 7 is a superimposition graph showing the differences between

---

69 Braun is a trade mark of a German manufacturer of electrical and electronic products.
70 Krups is a trade mark of a German manufacturer with a similar style to Braun's.
the two styles in all aspects. Generally speaking, these two styles are in opposition on almost every salient attribute; e.g. while Bauhaus is harmonious, homogeneous, ordered, geometric, pure, simple, modest, logical, functional, practical, unornamented, mechanistic, white/grey/black, timeless, minimalist and abstract in form; Memphis is contrasting, heterogeneous, disturbing, organic, impure, complex, radical, illogical, decorative, mis-

**Figure 4** Products of (a) Bauhaus style and (b) Memphis style
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Figure 5 The Style Profile of the Bauhaus style

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Figure 6 The Style Profile of the Memphis style

chievous, strangely decorative, playful, brightly colored, faddish, fantastic, and referential to pop art and popular culture. The values in the other two columns essentially echo each other except on a few attributes in the column of importance indices. This reveals that both styles place relatively equal emphasis on the salient attributes, while the relatively obvious discrepancies shown in the column of confidence factors are a reminder that the Bauhaus style has a stricter and narrower range than that of the Memphis style. Beyond their previously defined functions, the confidence factors and importance indices can also, of course, be regarded as indicators.
![Table with attributes and values]

Figure 7 The superimposition of Figures 5 and 6

of the evaluator’s personal biases or intentions regarding the description or generation of a specific style.

Figure 8 shows products from Braun and Krups. They look much alike, and all belong to the so-called Bauhaus style or German style. Figures 9 and 10 are the Style Profiles for these products — Braun and Krups, respectively. Figure 11 shows the superimposition of the two.

Generally speaking, these two styles hold similar positions on almost every salient attribute, e.g. they both are considered harmonious, homogeneous, geometric, pure, simple, functional, unornamented, mechanistic, white/grey/black and abstract in form. The values in the columns of importance index of the two are also very much the same. Under close examination, minute variations between the two can only be found in the confidence factor columns on a few attributes: simple–complex, balanced–unstable and static–dynamic. In these, Braun always has the simplest and most balanced form elements, and the most static structure, while Krups is slightly more relaxed.71

2.4 Summary

The proposed Style Description Framework presents an approach to the description of styles utilizing the concepts of semantic differential and class–subclass relationships. Within the framework, existing styles can be analysed and new styles planned by using Style Profiles with polar adjective pairs to describe attributes associated with a style, confidence factors to refine the scope of the style and importance indices to differentiate

---

71 In Figure 8, Braun’s coffee maker uses cylindrical form for both filter and base while Krups uses cylindrical for one and cuboid for the other; and the arrangements of the switches of the two products are also different. Other evidence can be found in coffee grinders.
![Image of product designs](image)

**Figure 8** Products from (a) Braun and (b) Krups

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| Joining Relationships         |                 |                   |                  |
| Uniform - Multiform           |                 |                   |                  |
| Angular - Rounded             |                 |                   |                  |
| Functional - Decorative       |                 |                   |                  |
| Subtle - Bold                 |                 |                   |                  |
| Harmonious - Contrasting      |                 |                   |                  |
| Single - Multiple             |                 |                   |                  |
| Hard - Soft                   |                 |                   |                  |
| Mat - Glossy                  |                 |                   |                  |

| Materials                     |                 |                   |                  |
| Color                         |                 |                   |                  |
| Treatments                    |                 |                   |                  |
| Harmonious - Contrasting      |                 |                   |                  |
| Single - Multiple             |                 |                   |                  |
| Cool - Warm                   |                 |                   |                  |
| Hard - Soft                   |                 |                   |                  |
| Texture                       |                 |                   |                  |

**Figure 9** The Style Profile of the Braun products shown in Figure 8

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weights of the attributes. Styles described within the framework have the characteristics of objects (in computer science terminology), and can be retrieved, modified and instantiated with ease by computer. In a forthcoming article, the authors will propose a form modelling infrastructure to associate the style information produced by the Style Profile with a form under construction.

3 Conclusions and suggestions
Designers create styles and use them to satisfy consumer tastes. However, the means by which styles are recognized, described and applied are very
poorly developed. This study has attempted to bring some understanding to the problem of style description. In this concluding section, the achievements of the study are summarized and directions for future research discussed.

3.1 Achievements
The objectives of this research were: to provide designers with a language that can communicate style to computers; to assist designers in analysing the stylistic attributes of objects (products); and to help designers to accumulate style-related knowledge. In fulfilling these objectives, this research accomplished the following:

- Formal style analysis mechanism: the Style Profile, with its bipolar adjective pairs covering the essential stylistic attributes of form elements, joining relationships, detail treatments, materials, colour treatments and textures (six major categories) can also serve as a mechanism for comprehensive formal analysis. By plotting Style Profiles on a chart, designers can directly compare the stylistic attributes of objects (products).

- Formal style knowledge accumulation framework: by recording the essential properties of specific styles, the Style Profile serves as a framework for formal style knowledge accumulation. By accumulating Style Profiles that record market preferences, cultural preferences, corporate identities or individual designer’s characteristics, designers can build knowledge bases for styles that can be reused almost effortlessly whenever they are applicable.

- Computer-comprehensible style description language: The Style Profile is a frame-like data storing structure, as well as a data communicating language in which attribute-value pairs are recorded. Values are converted (for recording) from bipolar adjective pairs, the component vocabulary of the style description language, to a normalized 0.0–1.0 scale. Through the Style Profile, designers can begin to communicate stylistic concepts to the computer for form generation.

3.2 Suggestions for future research
To bring the proposed style description framework to its full realization as a key part of an integrated computer-supported design system, a number of actions need to be taken. Two major areas of effort are worth mentioning.

Modelling infrastructure: a form-modelling infrastructure is needed that is better suited to the designer’s intuitive ability to manipulate forms than are currently existing modelling methods. Such an infrastructure should be
capable of converting the stylistic information stored in a Style Profile into geometric form representation while relieving the designer of problems of mathematical representation and manipulation during the processes of making spatial allocations, establishing joining relationships and treating details.

System integration: The Style Profile is a major step toward achieving computer-supported design systems that can respond directly to issues of style. However, such systems should also free designers of the repeated need to construct geometric models with the same types of detail treatment. Freed of this drudgery, designers can use their time more effectively to investigate style diversity and the appropriateness of different formal treatments for different cultures, corporations, distinctive designers, market segments — and even individual consumers.