Analysis of Geometric Features of 3D Shapes on Perception of Product Appearance for Visual Brand Affiliation

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Abstract. Products can be assigned to a brand by their visual similarity. An important factor here is the shape of the products. Previous methods for determining similarity for brand affiliation can only be applied to products with the same layout. For products with different structures (e.g. power tools), no methods exist for the 3D shape. Here, there is a need for research in order to be able to specifically design products similarly (or dissimilarly) for brand affiliation. The shape parameters that are independent of layout and are highly relevant for this purpose are determined on the basis of the perception (evoked feelings) of shapes. The approach implies that the communication of the corporate identity also takes place via the product appearance. Similar perceptions of the products lead to a perceived similarity. The results are based on a literature review of research in the field of affective design, emotional design and kansei engineering. The following 3D shape parameters were determined as important in descending order: edge/corner type, line and surface type, element amount (number of lines/edges and surfaces). Furthermore, the shape parameters are specified in 3D space.

Keywords: Affective design · Perception · 3D shape · Brand affiliation · Industrial design

1 Introduction and State of the Art

The product appearance has significant influence on the consumer acceptance and success on the market [1]. It is very important to be competitive with other products within the same category [2]. An important part of product appearance is brand recognition and affiliation. Aesthetic product design leads to positive brand evaluations and serves to categorize products and brands, influencing customers' opinions of the product and brand [3]. The visual assignment to a brand can be abstracted based on a high degree of similarity between the products [4].

In addition to color, graphics, and logos, brand affiliation can be achieved through similar shape language. Previous research regarding shapes mainly considers products with the same layout (e.g. cars) [5]. Relevant shape features for brand affiliation are identified and compared between products. Mostly, only outlines and contours of the

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shape features are considered in 2D representations (e.g. [4, 6]). This assumes that the same shape features are found in largely identical positions in all products. For product portfolios with products of different layouts (e.g. power tools) these procedures are not possible. Here, the complete use of 3D shapes (specific freeform surfaces) must be considered. With this knowledge about relevant shape parameters and their characteristics and weighting, products can be designed in a targeted, efficient and brand-specific manner. There is a need for research in this area. Only Wallace and Jakiela [7] mention the importance of corner design in this context.

In order to determine relevant shape parameters, an approach based on research in affective design, emotional design and kansei engineering is presented. This is based on the fact that products have an impact on the user through their physical attributes [2]. In addition, brands have identities (corporate identity), which in turn are ideally also communicated through the brand's product appearance [8]. Accordingly, it is assumed that similar (or dissimilar) product perceptions have an impact on brand affiliation. From this, it is concluded that shape parameters, which have a large influence on the product perception, are at the same time relevant for brand affiliation.

The paper presents an approach to the relationship between shape and perception of product shapes for brand affiliation based on a literature review of research. From this, recommendations for the use of shape parameters for brand affiliation are derived and specified.

2 Approach

The direct link between product shape and brand affiliation has already been discussed in many studies [5]. In some cases, the product perception has also been mentioned [6]. One research uses shape perception as a bridge between geometric properties and the determination of brand recognition and design freedom [9]. An important factor for the perception of products on users is the product shape [2]. According to Norman's model [10], emotional design consists of three parts: visceral design (appearance), behavioral design (pleasure and effectiveness of use) and reflective design (self-image, personal satisfaction, memories). In this context, the visceral response is particularly relevant as the first impression of the product design. Kim et al. [11] summarizes that affect is an object-oriented impression of the product, while emotion is an introspective feeling to external or internal events. Since the two terms are closely related, they are used interchangeably in research [12]. Part of kansei engineering is to design the product in such a way that intended feelings are evoked [13]. The corporate identity, or the character of a brand, is intended to create a unified impression among the products of a brand for brand affiliation [8].

Accordingly, the direct link between shape and brand affiliation can be used on the one hand, and the indirect link via the perception of shapes on the other (see Fig. 1). However, previous methods for the direct link between shape and brand affiliation are largely layout-dependent and based on single shape elements [5]. In order to determine structure-independent shape parameters for brand affiliation, the indirect link is used backwards. The identified layout-independent shape parameters (influencing product perception) can then be used to subsequently influence brand affiliation. The specific perceived properties of the shapes are not important for the time being. The two ways from the shape to the brand affiliation and this approach are visualized in Fig. 1. With the new approach it is possible to influence the relevant shape parameters on the basis of the findings on the perception of shape and in this way to establish characteristics for brand affiliation.

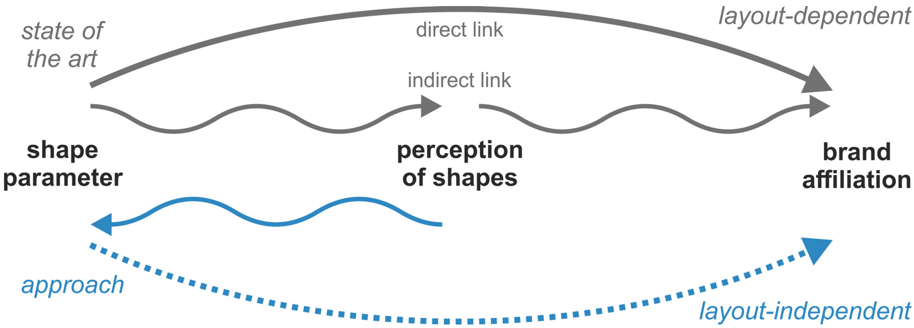

Fig. 1. Visualization of the direct and indirect link between shape parameters and brand affiliation (layout-dependent) and the approach (layout-independent)

3 Literature Review on Product Perception of 3D-Shapes

Publications are analyzed which deal with the perception of 3D product shapes by means of structure-independent shape parameters. Independent shape parameters are functionally neutral and describe mainly the general (global) surface usage. This overall shape definition already has meaningful effects [14]. Further requirements for the publication are that the products are shown in 3D surface form and not only in line form. The context of industrial design is also important. Accordingly, size, volume, composition (including symmetry) and orientation are not relevant. Also the combination of several shape parameters to terms like "organic" or "geometric/angular" are not purposeful (e.g. [15–17]). The overview (Table 1) is structured according to author, year, naming (terms instead of perception), example product, studied shape parameters (including mentioned shape characteristics) and type of research. In the case of the shape parameters, it is also indicated which shape parameters were found to be particularly significant within a study. Only the relevant shape parameters are mentioned in the overview. Most studies have also investigated a variety of other non-shape factors, which are not the focus of this paper.

Table 1. Overview of determined shape parameters and their characteristics

Author, year and *naming*	Shape Parameter and characteristics	Product	Type
Chen and Owen 1998 [18] *Stylistic description*	Edge type (sharp, step, fillet, bevel, round) Corner type (sharp, step, fillet, bevel, round) Face type (radii)	Cube, (furniture)	Proposed method
Pham 1999 [19] *Aesthetic properties*	Curvature (smoothness of transitions, change) Convexity Surface type (plane, single/double curved, warped) Number of features Line/curve type	-	Literature analysis
Chuang and Ma 2001 [20] *Product image*	Corner type (small, large rounded) Convex curvature surface	Micro-electronic products	Survey
Hsiao and Tsai 2005 [21] *Product image*	Line (different arcs) Surface (different arcs (convex)) Fillet radius (different radii or sharp)	Electronic Door lock	Proposed method
Hsiao and Chen 2006 [22] *Affective responses*	Corner type (sharp, large arc)** Surface type (flat, curve)* Line type (straight, curve)* Element amount (less, more)*	Kettle, sofa, automobile	Survey and experts
Perez Mata et al. 2017 [23] *Product perception*	Lines ratio (straight/curved)* Complexity level (number of modules)* Corner ratio (curved/sharp)	Vase	Survey
Kapkın and Joines [24] *Perceived meaning*	Edge roundness (radii)* Edge and corner roundness (radii)*	External hard drive, soap dispenser	Survey

* & ** [22]: high ranked by experts; * [23, 24]: significant impact

4 Results and Discussion

Based on the number of mentions and the characteristics, a tendency can be determined. The corner type is named most frequently, distinguishing between sharp and curved with different radii. Only one publication mentions further corner types [18]. Subsequently, surface type and line type are mentioned by most authors. Characteristics are flat and different curvatures for the surface type and straight and curved for the line type. Third most frequently the number of elements and the edge type are mentioned. In addition, one publication mentions convexity and curvature in general [19].

The authors of the researches from Table 1 only partially use the same terms for the shape parameters and vary in their number. It should be emphasized that only in two publications [18, 24] corner and edge are mentioned at the same time. All other publications use only one of the terms. Moreover, it becomes clear that edge and corner type are usually identical [18]. Therefore, a suitable 3D shape description model is developed for the interpretation of the results.

4.1 Model for the Description of 3D Geometric Shape Parameters

The description of 3D freeform surfaces can be done locally based on the curvatures at each point [25]. Globally a distinction between surface and edges (surface boundary) is necessary. A surface is characterized by a largely monotonous curvature [26]. In contrast, an edge is characterized by high relative curvature changes. Edges can be visually perceived by shading with large gray differences [27]. In extreme cases, an edge is not rounded at all, or is rounded to such an extent that it no longer exists as an edge and no longer represents a surface boundary. The differentiation of line and edge refers to the creation of surface patches with lines as boundary [28]. Thus, the surface contains properties of the lines. If two surface patches do not have a continuous transition, a hard edge is created along the separating line. If this non-continuous transition is rounded, the edge along the line becomes softer (see Fig. 2). In the case of a continuous surface transition, the separating line between the surfaces is not visible. The edge is, so to speak, the cross section along the line. The smaller the rounding of the edge, the more clearly the underlying line is recognizable. A corner is created when three or more edges meet.

Among other things, the 2D description of a corner leads to ambiguities in the interpretation. Here the combination of two lines is sufficient. Thus, an edge that runs along a line in the direction of view can also be interpreted as a corner. This ambiguity and the 3D shape description model are visualized in Fig. 2.

4.2 Interpretation of the Results with the 3D Shape Description Model

If we assume that corner type and edge type are mostly identical [18] and that edges are often interpreted as corners according to chapter 4.1, edge and corner can be combined into one parameter "edge/corner". This is supported by the largely identically named characteristics of edge type and corner type (sharp, curved/radius/arc: roundness). Accordingly, this shape element would also be the most important for shape perception. This is supported by the studies of Kapkın and Joines [24], according to which even small changes in the roundness of the edges already have an effect on the

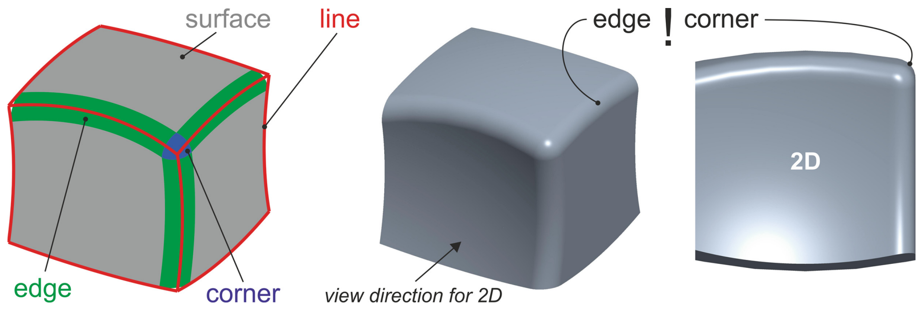

Fig. 2. Visualization of 3D line, face, edge, corner and the ambiguity of interpreting corners in 2D view.

perceived meanings. Wallace and Jakiela [7] also confirm this high relevance for brand affiliation. In the following, line type and surface type can be mentioned as the next important shape parameters. These are also described by Hsiao and Chen [22] as almost equivalent. In the case of surface patches, they cannot be considered completely separately, since they may influence each other. Line and surface types are described mainly by their curvature. Only two publications go into further details of curvatures of surfaces (especially convexity [19, 20]). As last relevant factor the number of elements can be described. Here the number of edges or lines and surfaces on the product is relevant.

In general, the research does not provide any information on the extent to which these shape parameters influence each other. Moreover, only the simpler shape characteristics have been researched so far (e.g. different radii). Further details of the edges, lines and surfaces, such as the style properties mentioned by Giannini et al. [26] (e.g. tension, acceleration) have not been investigated in this context so far. It should also be noted that the relationships between the geometric factors and their perception do not have to be linear [24].

5 Conclusion and Outlook

This paper describes an approach to determine relevant shape parameters for the brand affiliation of products with different layouts. For this purpose, the assignment to a brand by similar shape perception of the products is used. For the determination of relevant shape parameters, research in the field of affective design, emotional design and kansei engineering was analyzed. For the interpretation of the results, a general model for the 3D shape parameters was created. As a result, the following shape parameters are relevant for the product perception with their characteristics in descending order: edge/corner type (sharp, different radii), line and surface type (straight, different curvatures and flat, different curvatures), element amount (number of edges/lines and surfaces). This order also corresponds to the recommendation of the shape parameters for the generation of brand affiliation or differentiation on the market.

As a next step, the shape parameters determined should be validated in the context of brand affiliation. It is also interesting to see to what extent the shape parameters influence each other and how large geometric changes may be for assignment to a brand. It should also be investigated whether further details of the shape characteristics according to Giannini et al. [26] (such as tension and acceleration) can be used for brand affiliation.

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