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TERMINOLOGY USED FOR SHAPE IDEATION

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1. Introduction

The process of shape design changes as the design proceeds. In the beginning, the designer thinks of all kinds of shapes and considers many variants. Multiple variants may be developed simultaneously and elements of different variants may be combined into a new shape. This phase, which we will call ideation, is followed by the selection of one or several variants that will be elaborated. After the main decisions are made, the shape will be worked out in detail. In this detail phase, it is likely that a CAD system is used. CAD modelling, in general, requires that exact and complete data of the model is available. For ideation, sketching is frequently used. Sketching can serve as a sort of conversation between the designer's imagination and tacit representations. Sketching allows a designer to quickly record and present ideas on paper. Exact detailing can be postponed, thus enabling the designer to keep in pace with the creative process of imagination. With CAD modelling, this is not possible. A typical CAD operation requires much more time than putting a stroke on paper. Furthermore, CAD modelling requires a careful planning of necessary modelling steps and exact specifications of parameter values. These planning and specification jobs interfere with the creative exploration of shape. The use of CAD for ideation can result in less creative results than working with physical models [Charlesworth, 2007]. Several experimental software systems show that there are possibilities to make tools that are more appropriate for shape ideation. [Rusak, 2003] demonstrated a system for vague modelling and Varga (2007) proved that hand motions can be used for conceptual shape design. For successfully supporting shape ideation, the support software should match the way the designer works during the ideation process. [Wiegers, 2000] observed designers at work to and inventoried their activities. Observing the activities designers perform gives insight in their processes, however, it still does not show the way they imagine shape. We want to know in what terms a designer thinks about shape and about shape modifications. Thoughts of designers cannot directly be observed. We can only observe what is externalized, e.g. verbally or by sketching. The importance of sketching is well known [Tovey, 2000], however, the role of verbalization is often under-estimated [Johnson, 1995].

2. Method

We designed an experiment in which subjects have to imagine a shape modification and express this modification. Several ways exist to let a subject verbalize what is in his mind. A subject can, for example, be asked to 'think aloud', that is, to verbalize his thoughts. However, subjects may be incomplete in the reporting of their thoughts, and the verbalization of their thoughts can slow down their creative thinking. To overcome these problems, a more natural setting can be used in which one subject *(A)* has to explain his idea to another subject *(B)*. In this setting, it is obvious for *A* that he should give a sufficient explanation. Furthermore, *B* can ask for more details if the communicated shape is not yet clear. We used this method for our experiments.

The experiment was performed with multiple pairs of subjects. To be able to compare the results, we want to use the same shapes for each pair of subjects, instead of letting them design their own shapes. Thus, at one hand we want to have control over the shapes, but at the other hand the experiment should go beyond just describing an existing shape. To invoke *A* to describe a shape modification, rather than just a static shape, *A* is presented a picture of an initial shape and a picture of a shape that is derived from it. *B* sees only the initial shape and *A* explains to *B* how the initial shape should be modified. From this explanation, *B* sketches the derived shape. Fifteen different shapes are used. Ten of them are clay models with shapes that are not derived from existing products, to prevent that *A* can explain the shape by just mentioning its product name. For the remaining shapes, five existing products are used.
We want the subjects to use terms that they will naturally choose for the shapes they describe. Thus, we let the subjects speak in their native language, which was Dutch for all subjects. In this paper, we translated the terms into English terms with the same meaning. However, because a translation is not a simple one-to-one mapping, it is still possible that English-speaking people would choose different terms in some cases.

3. Expectations

Subjects who describe a shape idea often start with mentioning a shape instance that looks much like the target shape. This shape instance may be a geometrically defined shape, like a cube or a cylinder. It can also be the shape of an object from the subject's environment, like a bottle, a car or a dog. We will call this a metaphor. Metaphors are not always well defined. The concept of a car, for example, may be different between two subjects. This need not be a problem, because the listening subject can ask extra information. However, misunderstandings may occur when the subjects are not aware of their different interpretations. Proper feedback can prevent such misunderstandings.

Table 1. Categories of shape terms

	Categories
1	Geometric shape instantiation
2	Metaphor shape instantiation
3	Boolean operation
4	Geometric operation
5	Handicraft operation
6	Location
7	Dimension
8	Absolute value
9	Relative value
10	Fuzzy value
11	Geometric shape characteristic
12	Vernacular shape characteristic
13	Emotional shape characteristic
14	Course
15	Need to change

After mentioning a shape instance, the differences between the mentioned shape and the target shape can be explained. It may be necessary to add or remove particular shape elements, so Boolean operations can be expected, together with terms that specify the location where the modification should be applied. Furthermore, there may be differences in particular dimensions and shape characteristics. As dimensions, we can expect length, width, height, depth, thickness, distance, clearance, etc. The values of those dimensions may be expressed in absolute numbers or in relative terms, like 'half of that length', or 'twice as deep'. Fuzzy values may be used, such as 'a bit longer'.

Fuzzy values can sometimes be classified as relative (about 80% of its height) or absolute (two or three mm), but many fuzzy values can be interpreted in both ways (a big one, somewhat taller). Furthermore, we can expect shape characteristics, expressed in geometric terms (parallel, concentric), or in more popular or vernacular descriptions. In addition, subjective terms may be used that carry an emotional value (modern, old-fashioned, cool).
Instead of mentioning a particular shape characteristic, the subject may explain how the characteristic can be obtained by applying a particular operation. Some operations are geometrically defined (e.g. rotate, scale, mirror), other operations may stem from a handicraft (saw, cut, bend). In the ideation phase, we don't expect many operations that stem from manufacturing, such as welding, injection moulding or milling.
If it is difficult to express the shape details, subjects may switch to another approach: guiding the pencil of the sketcher, as if they were sketching themselves. Terms can be expected that describe the course the pencil has to go, like 'to the left', 'from the beginning' and 'slightly curved'.
At the end, some additions and corrections can be made. The corrections may include negations and other terms that express the need to change the shape, e.g. 'not this, but that'. Summarizing, we find fifteen categories of shape terms, as shown in Table 1.

4. Results

In total, 1796 terms were used for the explanation of 15 shapes by six pairs of subjects. On average, this makes about 20 terms per shape description. The shortest shape description was only 2 terms (*slimmed down* and *pilot spectacles*), while the longest one consisted of 39 terms.

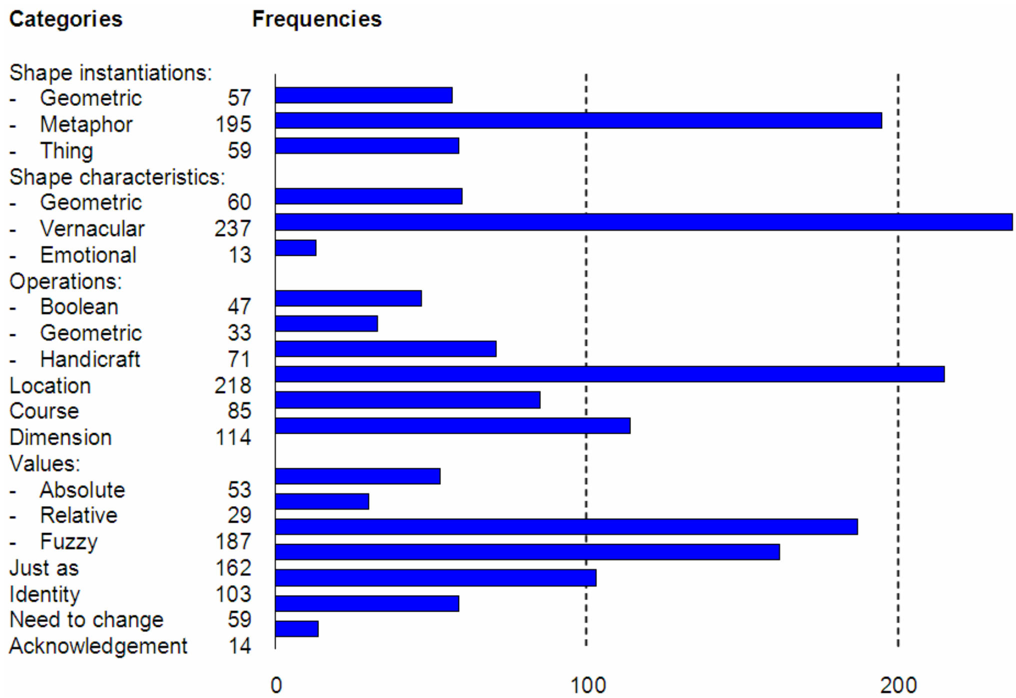

Figure 1. Frequency of terms for each category

Of all terms, 81% could be assigned to the above-specified categories. For the remainder we specified four additional categories. The category *Thing shape instantiation* was added for things that were just called by their names. This did not happen for the clay objects, but it did happen for the products that were used. These terms could not be categorized as Metaphor shape instantiations, because a metaphor implies that the name of one object used to describe another object, not the object itself. A category *'Just as'* was added, because a shape element was often described by comparing it to another object, e.g. 'a shape just as an hourglass'. A category *Identity* was added for terms that identify a particular part of a shape, e.g. 'this part' or 'the top side'. Finally, a category *Acknowledgement* is used for the word 'yes', which was answered when *B* asked if the sketch were correct. This makes 19 categories in total. Figure 1 shows the categories and the frequencies of their terms.

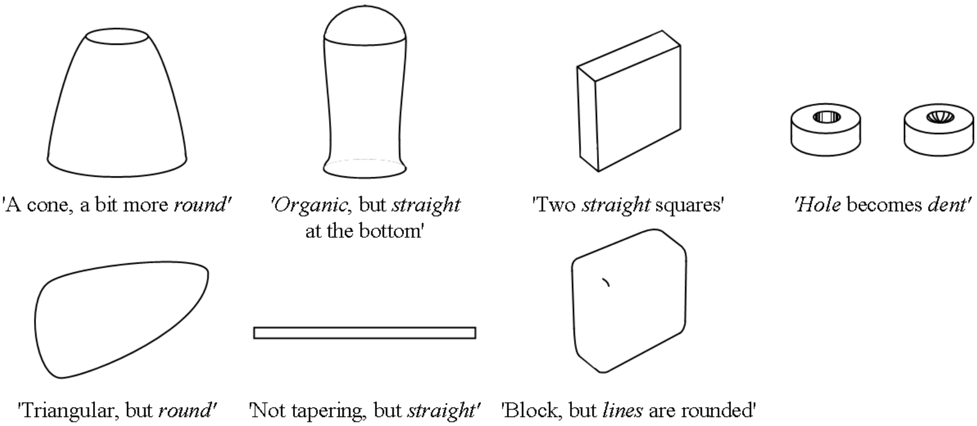

Figure 2. Examples of frequently expressed vernacular shape characteristics

We will look in more detail to the seven largest categories, those who contain over one hundred terms. '*Vernacular shape characteristics'* is the largest category. With 237 terms, it is nearly four times larger than the category of *Geometric shape characteristics*. The most frequent terms in this category are *'round', 'straight', 'line', 'hole'* and *'point'*, the latter with the meaning of something that has a sharp end, see Figure 2. *Emotional shape characteristics* is the smallest category, with only 13 terms. Ten of these 13 terms were used for one of the real products. The second large category is that of *Location*, with 218 terms. *'Top'* and *'under'* were the most frequent terms for locations. In the third place is *Metaphor shape instantiation*, with more than three times as many terms as for *Geometric shape instantiation* (195 and 57 respectively). The most used metaphors were *'bridge', 'leg' and 'boat'*. Category number 4 is *Fuzzy values*, with the terms *'more', 'a bit more', 'a bit'* and *'some'* as the most frequent ones. The fifth place is for the *'Just as'* category, in which the terms *'become', 'sort of'* and *'same'* occur most frequently. The category *Dimension*, with 114 terms, contains terms like *'wide', 'large', 'long'* and *'thick'*. Finally, still more than a hundred terms can be found in the category *Identity*. Most used terms for identification were *'that'* and *'part'*. Below we will zoom in on the terms in the mentioned categories.

Table 2 shows the terms of *Vernacular shape characteristics*, in order of frequency. '*Round'* explained that a cross section is circular, or, at least, not sharp-edged. The term was also used when not a complete circle is concerned, but half a circle, or a quarter of a circle, or a part of a sphere.

Table 2. Vernacular shape characteristics

F	Terms
24	round
13	straight
10	line
9	hole, point (sharp end)
7	Sharp, Dent
5	organic, flat, crooked, protrude
4	base
3	turn, arch, recess, bend, long, pointed
2	bump, contour, curve, closed, undulating, edge, sharp-edged, crack, tag, oblong, gap, ridge, rounding, jagged, separation, offshoot, protrusion, decrease
1	80 other terms

Besides, *'rounds'* was used to indicate the turns of a spiralling object. The term *'straight'* indicated that a surface is flat, or has parallel edges, or that an edge is not curved. *'Line'* indicated edges or ridges. In some cases, it depicted a virtual separation between two parts. *'Hole'* denoted a through-hole, while *'dent'* was used for a concavity in a surface. *'Organic'* suggested double curved surfaces.

The *Location* category counts 103 different types of terms. They can be divided in subcategories that are related to an object's *top, bottom, middle,* or *front*. Additional subcategories are related to *left, behind, in, side* and *right*. These nine subcategories contain 151 terms. There remain 67 terms that occurred less than four times. Table 3 gives an overview of the location terms.

Table 3. Location terms

Subcategory	F	Terms
Top	55	top side, upper, on top, on top of, at the top, above, up, top view
Bottom	27	bottom side, lower, under, at the bottom, beneath, in the depth, down
Middle	19	halfway, middle, centre, in between
Front	12	front side, front view, before, front face
Left	10	left side, to the left, left one, left, left face
Behind	8	back side, behind, rear
In	8	in, in it
Side	7	side face, at the side
Right	5	Right, right one, right side, to the right
Other	67	Different terms that occur less than 5 times

Metaphors occurred 195 times. Body parts and animals were rich sources for shape metaphors. In addition, fruits and foods were used, and a large variety of man made objects. In addition, more vague or abstract object descriptions were used, such as arch, barrel, beam, slice, spout, and tube (Table 4).

Table 4. Metaphors

Subcategory	F	Terms
Body	27	leg, nose, bite, head, finger print, foot, rear, arm, thumb, heel, neck, shoulders, tooth
Animals	24	shell, proboscis, snail, snail-shell, serpent, beast, bee, rooster's leg, camel, camel back, sea-gull, elephant, caterpillar, tusk, tail, bird
Nature	22	potato, apple, pear, cherry, stem, core, leave, shit, turd, mountain
Food	9	donut, hamburger, fritter, pancake, roll, liquorice, sausage
Products	34	car, Cadillac wing, boat, cabin, rudder, bow, board gun, rocket, bridge, gate, circuit, stage, platform, roof, ball, curling grip, diabolo, hour glass, plate, soup plate, dish, Extran bottle, pedal, brace, wire, grip, arrow, collar, cap, flap, hat, purse, shadow, sword
Vague	35	arch, barrel, basket, beam, blob, bowl, bullet, bump, cone, cover, curl, dome, edge, eight, equator, garland, hollow, line, lobe, passage, ridge, ring, round, slice, spout, string, stripe, swell, thing, tip, tube, v-shape, wedge

The category of *Fuzzy values* contains 116 terms that indicate *'more'*, and 39 terms that mean *'a bit'*. The remaining terms express values such as *'very ', 'quite', 'almost', 'about'* and *'such'* (Table 5).

Table 5. Fuzzy values

Subcategory	F	Terms
More	116	more, a bit more, some more, just a bit more, yet more, a bit more that this, a bit more exaggerated, much more, still much more
A bit	39	a bit, some, a little bit, a small piece, somewhat, just, light
Very	8	indeed, really, very, pretty, strongly
Quite	5	quite, rather
Almost	5	almost, not quite, even almost, hardly visible
About	4	about, as if it were
Such	4	such, something like that
Different	3	different, more a sort of, no longer quite
Other	3	most, a bit less, not bad

Just as terms can be subdivided in terms with the meaning *'same as..', 'looks like..',* and *'becomes..'*, respectively (Table 6). The most mentioned *Dimensions* were *'wide', 'large'*, and *'long'*, Table 7.
If particular shape elements were identified, most often the terms *'part', 'that'* and *'it'* were used (Table 8).

Table 6. 'Just as' terms

Subcategory	F	Terms
Same as ..	75	same, the same, remain, same shape, intact, copy, again, similar, etc.
Looks like ..	47	as, as if, just as, looks like, such as, such a, etc.
Becomes ..	40	become, make, towards, takes the shape of, etc.

Table 7. Dimensions

F	Terms
>10	wide, large, long
4..9	thick, narrow, high, small
2, 3	thin, low, sharp, width, diameter, thickness, deep, height, short
1	13 other terms

Table 8. Identity

F	Terms
>10	part
4..9	that, it, shape, thing, main shape
2,3	sphere, this, angle, the last part, leg, point, ball, cap, half, face, what
1	32 other terms

4. Discussion

Vernacular shape characteristics were expressed very often, nearly four times more often as geometric shape characteristics (237 vs. 60). In addition, metaphor shape instances occurred more that three times more often as geometric shape instances(195 vs. 57), and from shape operations, there were more handicraft operations than geometric operations (71 vs. 33). From this, we conclude that in human shape expression, geometrical terms do not play the main roll. Thus, a shape ideation support system must be able to understand more than alone geometrical shape descriptions. It must be able to understand characteristics such as 'round', 'sharp', 'dent' and 'organic'. Besides, it should recognize locations that are not indicated by coordinate values, but by expressions as 'at the topside', 'halfway' and 'on top of'. If a value was expressed, two out of three times it was a fuzzy value like more or a bit. Thus, for natural interaction with an ideation support system, it is important that the system can handle fuzzy values. Furthermore, it would be helpful if the system would understand shape metaphors. To a certain extent, it is possible to provide a system with more knowledge about existing shapes and fuzzy values. It is even possible to build a learning system, and make it recognize a new shape after a designer introduces it once. Still, we cannot expect that even a very advanced system will reach the same level of understanding as two designers who collaborate for several years. However, this is no problem. The goal of an ideation support system is not to replace a fellow designer, but to support a designer's creativity by enabling to focus on shape ideas, not on the operations that are necessary to make the shape ideas tacit.

Before an ideation support system can be built, a number of issues has to be elaborated. The system must be able to work with fuzzy data. This is because the created curves and surfaces will often be ill defined. For example, if a generated edge is not exactly circular, the system must still be able to make that edge more rounded. Another issue is that changing parameter values alone is not sufficient. The system must also be able to assign multiple parameter models to one shape, because different shape modifications may need different types of parameters. For example, making a shape flatter requires another view of the shape than making the shape more rounded. Ideating designers change their views frequently. Support systems for ideation must be able to do the same, if they should support the different operations the designer wants to perform.

5. Conclusions and further research

An inventory was made of terms that are used for shape ideation. Vernacular shape characteristics, such as *'round', 'straight', 'hole'* and *'dent*, occurred far more often than geometrical shape characteristics (e.g. flat and spherical). Locations were marked with terms like *'top', 'bottom', 'front'* and *'back'*. For expressing complete shapes, metaphors were used more than three times as often as geometrical descriptions. Most expressed values were fuzzy values, like *'more'* or *'a bit'*. Many times a shape was explained by comparison, using terms as *'the same as ..'*, or *'it looks like ..'*. Individual shape elements were identified by a variety of terms, in particular with *'part', 'that'* or *'it'*.
If a shape ideation system will be developed, it should be able to understand shape metaphors and apply fuzzy values. Moreover, such a system must be able to assign different parameter models to the same shape and apply the one that matches best the current operation of the designer.
As a follow-up of this research, the found terms will be used as a basis to propose digital shape operations and corresponding shape handles that are appropriate for shape ideation. Inquiries among designers will be organized to evaluate the proposals. The best proposals will be elaborated.

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