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SHAPE IDEATION TROUGH SHAPE METAPHORS

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1. Introduction

Shape ideation is the process of thinking out shapes in the early phase of design. In this phase, the possible appearances of products are studied and shape concepts are created. Exact dimensions are not yet important, and many details will be elaborated in later phases. Shape ideation is characterized by openness and broadness, but also by incompleteness and vagueness. Therefore, it requires an approach that is different from detailed shape design. Computer-aided design systems get more advanced through time, however, there are still complaints that they do not sufficiently support design ideation [Charlesworth 2007]. Ideally, a system that supports the ideation phase of shape design should have a human-computer interface that does not require much attention of the designer, but allows the designer to concentrate on the ideation of shape. To be able to develop such an interface, it is necessary to understand how designers work and think during the shape ideation process. We performed multiple studies to observe how people communicate shape ideas. A study on the use of different ways to express shape revealed that metaphors were frequently used to explain shape [Wiegers et al. 2000]. Another research identified terms that were used for shape ideation and categorized these terms [Wiegers et al. 2009]. The main categories are shown in Table 1.

Table 1. Shape term categories

Category	Description
Shape_instantiations	Terms to invoke an image of a complete shape (cube, car)
Shape_characteristics	Terms to express an individual shape aspect (spherical, hole)
Shape_operations	terms to express a shape modification (bend, cut)
Locations	terms to denote a particular location (top, front)
Dimensions	terms to specify a dimension (length, height)
Values	terms to indicate an amount (two, a bit)
Comparisons	references to other shapes or values (just as, more than)
Courses	terms to let a pencil move over paper (to the left, further, stop)
Confirmations	terms to tell the generated shape aspect is correct (yes, ok)
Negations	terms to tell that something must be changed (no, however)
Identifications	terms to identify a particular object or part (this, it)

The category of *Shape_instantiations* was further subdivided. This category contains geometrical shape instantiations (such as cube and sphere), physical shape instantiations (e.g. table, car), and shape instantiations that express the shape of a new object by using the shape qualities of another object (e.g.

pear for a light bulb). We will call them shape metaphors for short. These shape metaphors are the subject matter of this paper.

2. Metaphors

When we hear of metaphors, we may easily think of poems and prose. However, metaphors occur more frequently than we mostly are aware of. Lakoff and Johnson (1980) explain metaphors and show how they influence our thinking. Metaphors are used in all domains of our live. We found that metaphors also play a role in shape ideation [Wiegers et al. 2000, 2009]. Several definitions of metaphors exist. In general, they tell that a metaphor uses the construct of one object to explain another object. Lakoff and Johnson (1980) state: "The essence of metaphor is understanding and experiencing one kind of thing in terms of another." Fox (1989), who describes how metaphors can function in psychology, characterizes metaphors as follows: "Qualities literally connected with one object are transferred to another object, achieving new meaning." Fox mentions a large number of properties of metaphors, from which many are also applicable in the domain of shape ideation. We mention the following:

A metaphor

- is tentative
- compacts information
- teases perception
- stretches cognition
- stimulates recall
- alters perspective
- enables listeners to develop understanding in their own "language"
- helps to discover patterns and unite these into a holistic picture
- bypasses the rigid corridor of reasoning and logical analysis
- draws upon unconscious resources and allusions
- causes creative thinking of the maker and the interpreter
- invokes collaboration for understanding
- provides process fluidity, allowing interpretation changes during the process
- is not right or wrong, but just one of a range of possible metaphors

2.1 Richness of metaphors

A metaphor is flexible, because it transfers some of the qualities of the source to the target, but not all. Some metaphors transfer only one, or a few qualities. For example, "the foot of a mountain" expresses that the bottom part is meant, but usually does not mean that the mountain has toes. A counter example is an organization tree. This metaphor is able to transfer more then the properties of a trunk from which branches split off. It can also suggest that the branching is recursive, and with different numbers of recursion. Leaves may be seen as essential parts, without which the tree cannot more than survive. The transferred concept can further be extended with the breathing of the leaves, the grounding of the roots, and so on. Such an elaborated metaphor will be called a rich metaphor in this paper. In contrast, the foot-of-the-mountain is an example of a simple metaphor. Note that the richness depends on the application of the metaphor. The tree concept can be applied as a simple metaphor if it is only used to indicate that a road branches.

2.2 Multiple metaphors

In some cases, multiple metaphors are used to explain the same target object. Multiple metaphors can increase understanding [Lakoff and Johnson 1980]. They can clarify which qualities should be transferred and which should not. For example, if a shape is expressed as a trunk of an elephant, we may imagine a grey, bending tube. After the same object is called the stalk of an apple, we still assume it is shaped like a curved cylinder, however, not necessarily hollow or grey.

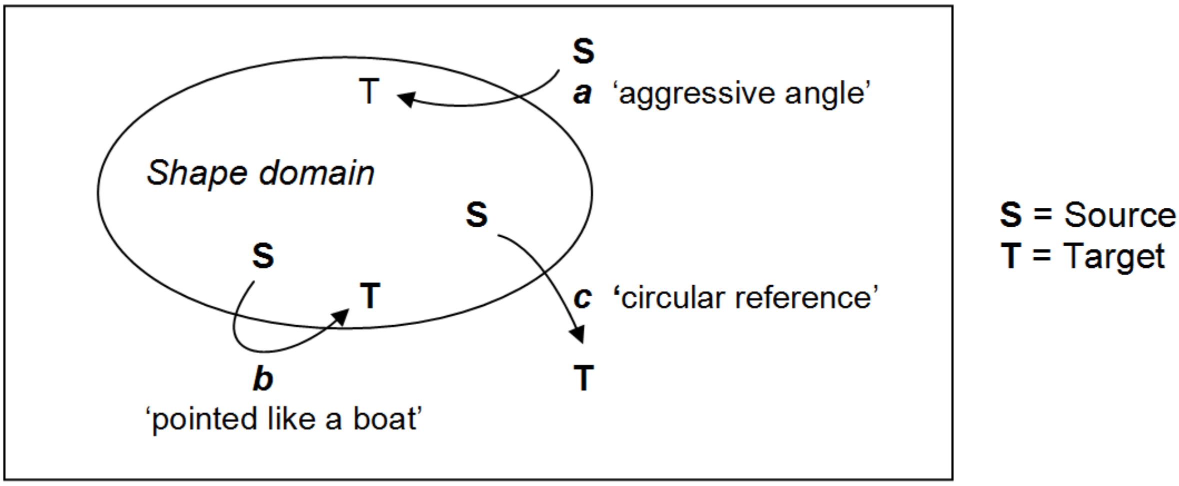

Figure 1. Only b is a shape metaphor (source and target are in the shape domain)

2.3 Shape metaphors

Above shape metaphors were characterized as expressing the shape of a new object by using the shape qualities of another object. Thus, a metaphor is not a shape metaphor if its source is not in the shape domain (e.g. 'an aggressive angle') nor if its target is not in the shape domain (e.g. 'a circular reference'). Only metaphors from which source and target are in the shape domain will be called shape metaphors, see Figure 1.

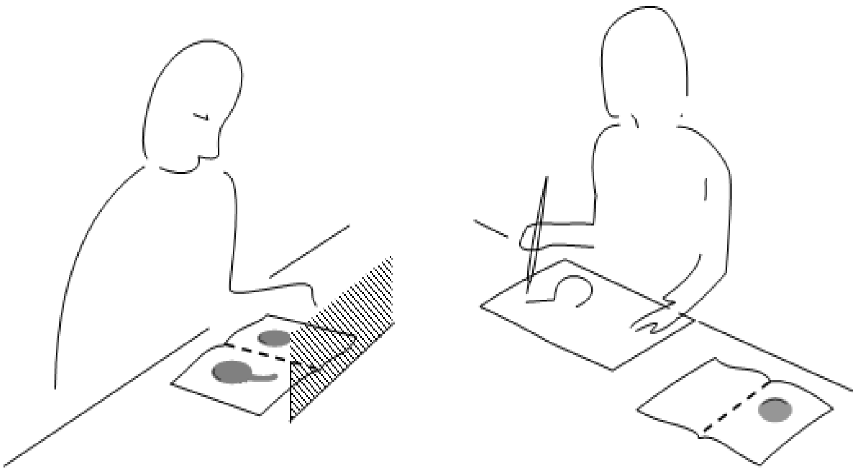

Figure 2. Set up of the experiment

3. Method

Shape metaphors were identified from the data of an empirical experiment. In this experiment, two subjects were acting, see Figure 2. Subject *A* had to express verbally the modification of a shape to subject *B*, who had to sketch the modified shape. Both subjects were shown the initial shape, but only *A* knew the target shape. The experiment was performed with fourteen subject pairs and ten different shapes. The subjects were first year bachelor students of design courses. Seven subject pairs were students of IPO (Industrial Product Design) of the Haagse Hogeschool and seven subject pairs were from IDE (Industrial Design Engineering) of the Delft University of Technology. For the ten shape pairs, we can use shapes of existing products, or shapes that are not models of existing products. The latter case has the advantage that subject *A* cannot fall back on standard nouns to describe the shape, but has to find shape terms himself. However, it could be possible that people describe such shapes in another way than the shapes of existing products. In that case, the results would be biased if we don't

Figure 3. The ten shape pairs used for the experiment, five pairs of clay objects and five pairs of product objects

use any real product shapes. We decided to use both types of shapes, five pairs of product shapes and five pairs of 'vague' shapes, modelled in clay. Figure 3 shows the shapes that were used, ten pairs of initial shape and target shape.

All verbal utterances were recorded. The shape terms that were used, were identified and categorized. The experiment and the found shape categories are described in Wiegers (2009). With the gathered data, we want to answer the following questions:

- How often were metaphors used?
- Did all subjects use metaphors?
- Were metaphors used for all objects?
- Were different metaphors used for the same object?
- Did individual subjects use multiple metaphors for the same object?
- Did multiple subjects use the same metaphor for the same object?
- Did metaphors transfer multiple shape qualities?

After answering these questions, it will be discussed whether a hypothetical support system could be able to recognize the found metaphors, and what requirements such a system has to fulfil.

4. Results

After the experiment, we categorized the shape terms that were used by the subjects. The category of shape metaphors was further analyzed. A list of all observed shape metaphors is shown in Table 2. The total number of shape metaphors was 146. There were 79 different types of shape metaphors, from which 23 were used by multiple subjects for the same object. The *boat* metaphor was used by 12 of the 14 subjects. Seven metaphors were used for more than one object.

Table 2. Observed metaphors with their frequencies of occurrence

Multiple occurrences	**f**	**Single occurrences (f =1)**	
boat	12	apple paring	Jetix puppet
ball	8 (5+2+1)*	ash tray	keppitel
stalk	7 (6+1)	Audi logo	meat ball
snail	5	bat	mountain
flier spectacles	5	boomerang	mushroom
car	5	boot / trunk	neck
snail's shell	4	bread roll	nib
egg	4 (2+1+1)*	bridge	Olympic games
beam	4 (2+2)*	burger	pear
apple	4	butt	Pokemon
helmet	3	carrot	Porsche
visor	3	cartoon	prickle
trunk	3	Carvan Cevitam bottle	ring
arm	2	cheese	ruler
cherry	2	chicken	sea animal
dome	2 (1+1)*	cow	snake
finger	2 (1+1)*	crater	steps
handle	2 (1+1)*	dim lamp	stick
horn	2	ear	strawberry
lava light	2	edulab	tail
rocket	2	fish bowl	thread
Santa crosier	2	flag	Tinkiewinkie thing
shoe	2	frisbee	vortex
snorkel	2	head	waterfall
waist	2	heart	woman
willie	2	hill	wine bottle
		house	

Types 79
Occurrences (total) 146

* These metaphors were used for multiple objects.
The frequency per individual object is added between parentheses.

Table 3 gives an overview of the shape metaphors, ordered to individual subjects and objects. All subjects used shape metaphors, for at least two objects. For all objects, shape metaphors were used, by at least three subjects. In total, in 79 of the 140 explanations, one or more shape metaphors were used. The maximum number of metaphors used in one explanation was five.

Table 3. Frequencies of metaphors per subject and per object

Object	Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Totals per object
1	Shoe		1	1						1			1	3		7
2	Cherry	4	4		4	3	1	2	1	2	2		3	3	1	30

3	Boat		1	1	1	4	4	1	1		2	3	2	2	1	23
4	Crosier	1	1	1	1	1	3	2		1		1	4	4	1	21
5	Boomerang		3	1	3	1	5		1		1	3		1		19
6	Chair					1							2			3
7	Bulb		1				1	1	1	1	2		1			8
8	Bottle		1		1		1	1				1	3		3	11
9	Bin		3		2								4	3		12
10	Spectacles	1	1		1		3	1	1	2		1			1	12
Totals	per subject	6	16	4	13	10	18	8	5	7	7	9	20	16	7	146

We observed fifteen occurrences of multiple metaphors, see Table 4. Eight of them were expressed by the same subject. Six more subjects used multiple metaphors, but only one or two times. Multiple metaphors were not used by all subjects (7 of 10) and not for all objects (9 of 14). One subject applied four different metaphors for the Cherry-shape. He called it handle, trunk, cartoon object and snorkel. In three cases, a subject used three metaphors for the same object.

Table 4. Frequencies of multiple metaphors

	Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Totals per object
Object																
1	Shoe													1*		1
2	Cherry	1**	2		2	1							1	1		8
3	Boat					1										1
4	Crosier							1					1*			2
5	Boomerang						1*									1
6	Chair															0
7	Bulb															0
8	Bottle														1	1
9	Bin		1											1		1
10	Spectacles															0
Totals	per subject	1	2	0	2	2	1	1	0	0	0	0	2	3	1	15

* The subject used three metaphors for the same object
** The subject used four metaphors for the same object

For each object, a variety of shape metaphors was used. Three different metaphors were used for the chair, and even 16 ones for the boomerang. However, metaphors used for the same shape did not always express the same quality of the shape. For example, for object 1, *shoe* was used to express the global shape, while *burger* expressed a part of the shape. *Steps* indicated the way individual parts should be arranged, and *Audi logo, rings* and *Olympic Games* were expressed to explain the overlap of the individual cylinders.

Table 5. Different types of metaphors used for the same object

Object	f	Shape metaphor types
1 Shoe	6	shoe, burger, steps, Audi logo, rings, Olympic games
2 Cherry	13	stalk, ball, apple, trunk, cherry, willie, snorkel, handle, cartoon, thread, paring, Tinky winky thing, finger
3 Boat	8	boat, car, house, bread roll, waterfall, boot/trunk, keppitel, Porsche
4 Crosier	12	snail, snail's shell, Santa crosier, beam, hill, bridge, snake, chicken, flag, sea animal, vortex, tail
5 Boomerang	16	ball, horn, arm, boomerang, frisbee, ash tray, cow, Pokemon, carrot, crater, mountain, finger, bat, prickle, Jetix puppet, meat ball
6 Chair	3	butt, egg, mushroom
7 Bulb	8	egg, pear, dim light, head, stalk, neck, ball, fish bowl

8	Bottle	8	rocket, lava light, waist, wine bottle, woman, dome, handle, Carvan Cevitam bottle
9	Bin	9	helmet, visor, nib, edulab, ruler, stick, dome, flap, cheese
10	Spectacles	6	flier spectacles, egg, beam, strawberry, ear, heart

5. Discussion

The results of the experiment show that many shape metaphors were used. About ten percent of them were multiple metaphors. The applied shape metaphors vary in richness; however, in general, they were not very rich. This may be because the experiment reflected an early phase of design and focussed on global shape, without much attention for subtle detail. The use of shape metaphors was not red to a few individual subjects, all of them applied metaphors. The use of multiple metaphors for the same object, in contrast, mainly occurred by one subject. Shape metaphors were used for all objects; however, we see a wide variety in frequencies here. One object, the chair, was only three times explained by a shape metaphor, while 30 metaphors were used for the cherry. Apparently, but not surprisingly, the shape has a considerable influence on the application of metaphors. More generally, this can be seen when the clay objects are compared to the product objects. For the five clay models, together 90 shape metaphors were used. For the product models, subjects used 46 shape metaphors, which is about 50% less.

Apparently, metaphors were more frequently used for shapes that are rather vague and not so crisp. Such shapes are most likely to occur in the ideation phase. The further the design evolves, the more the shapes will develop. This finding agrees with result from another study, which shows that metaphors are used in particular in the early phase of design, when ideas are generated. In the next phase, the conceptualization, designer use more often analogies, instead of metaphors [Hey et al. 2008]. Finally, during detail design, jargon will be more frequently used.

The frequent use of shape metaphors during idea generation raises the question whether digital systems can be developed that understand shape metaphors. To recognize a shape metaphor, a system should have knowledge about possible shape metaphors and the shape qualities they can transfer. However, the number of possible shape metaphors is endless, and their applicability depends strongly on the particular design situation. Therefore, a limited set of shape metaphors should be chosen. The contents of that set may vary, depending on the design situation. The selection requires a sort of prediction of the usefulness of shape metaphors for future ideation processes. The usefulness of a shape metaphor depends on the design discipline, the product type, the phase in the design process the experience and knowledge of the designer, etc. Because of these dependencies, an effective metaphor recognition system should be adaptable for the user's situation. It should be able to feed the system with metaphors that are applicable to the design discipline the user works in, and to the product types the user generates. Experience and knowledge will be different between users, so it may be useful for the system to maintain user profiles. Users should be able to learn the system new metaphors, and during ideation processes, the system may automatically learn new metaphors from the course of the process and the words the designer uses.

Because the recognition of shape metaphors depends on so many factors, the system should maintain a complex network of possible shape metaphors, the shape qualities they can transfer, and algorithms to estimate the probability that a shape metaphor is applicable in a particular situation. Figure 4 depicts a possible fraction of such a network.

Metaphors transfer some qualities of the source to the target, but not all of them. Which qualities are essential will not be clear from the beginning. Proper feedback is necessary [Wiegers 1999] to let the user evaluate whether the system's interpretation of the metaphor is appropriate or not. In this way, the transfer of the most essential qualities can be verified. However, there are also qualities that may be transferred or not, without disturbing the original intention. Thus, a metaphor introduces ambiguity and can be interpreted in multiple ways. A system that works with metaphors should be able to cope with ambiguity. It should allow re-interpretation of earlier input. Therefore, it is necessary that all input is tracked and associated with later input, if necessary. If a user want to change his interpretation of a metaphor, the system should still know how the metaphor was introduced, and in which context [Burger and Marshall 1998]. If a re-interpretation is necessary, the system might show the user a number of most likely interpretations. In this way, the system has an advisory function [Moore and

Paris 1998]. However, the system should be very modest with spontaneous proposals, because of two reasons. One reason is that spontaneous will attract the user's attention, and thus interfere with his idea generation. This can lead to irritation and less innovative ideas. The other reason is that, by showing proposals, the system can lead the user in a particular direction. A designer who frequently follows proposals of a system, may often come up with shapes that are not very different from the ones he designed earlier.

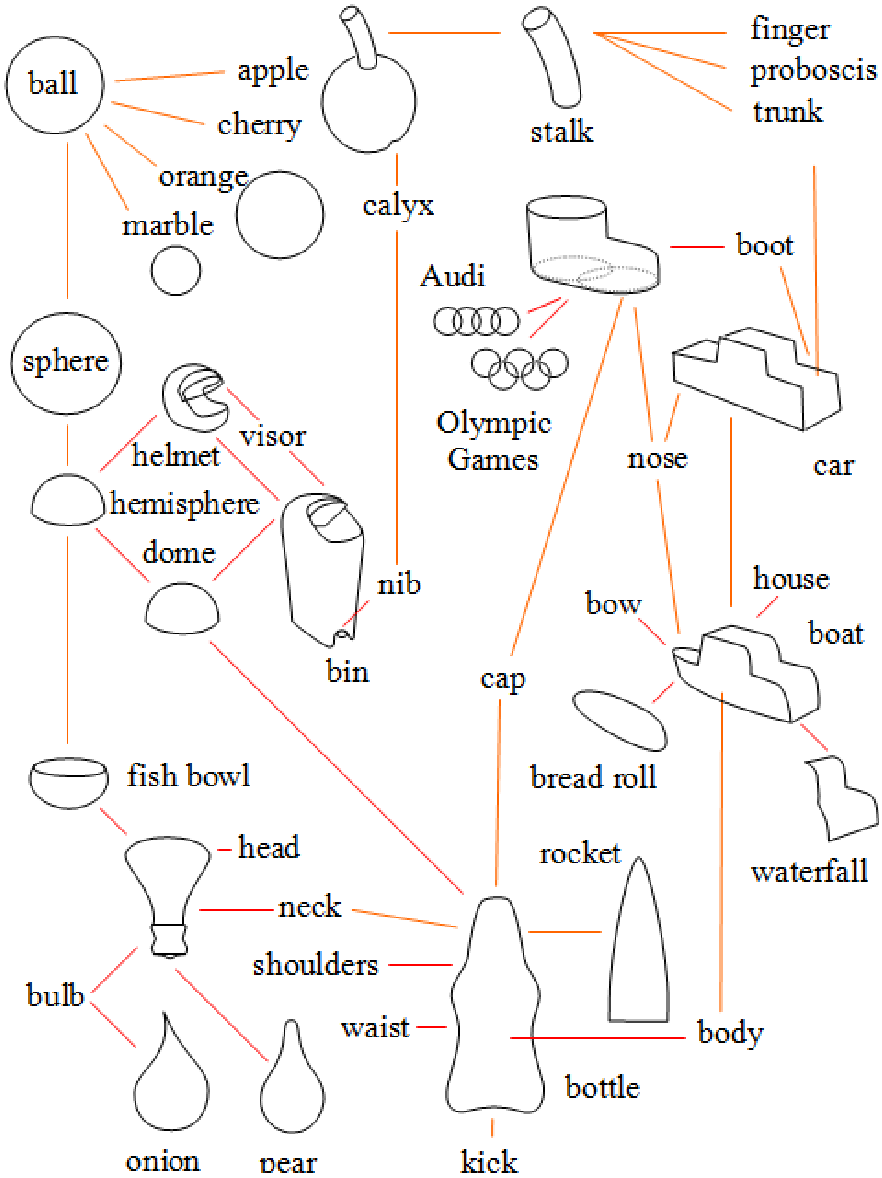

Figure 4. Possible fraction of a shape metaphor recognition network

6. Conclusions and further research

Shape metaphors can be powerful means to communicate shape ideas. They enable quick explanation of global shape, allowing the details to be explained later. Apart from the global shape, a shape metaphor can also maps a number of other shape qualities onto the target shape, such as locations and orientations of particular parts. Test subjects who had to communicate shapes, all used shape metaphors for some of the objects. Shape metaphors were applied to all objects, with varying frequencies. Vague clay objects were more often explained by shape metaphors than crisp products. Digital support systems could benefit from this way of shape communication. Understanding shape metaphors requires a complex network of possible shape metaphors, shape qualities they can transfer, and methods to estimate the applicability of a metaphor in a particular context. Besides, the system should track the user's input carefully. Furthermore, it should be possible to feed the system with metaphors that are relevant for particular disciplines and products. Preferably, the system must be able to learn itself new metaphors from the data a designer provides during idea generation processes. Further research is necessary to investigate how such a system can be implemented, and which metaphors should be provided to let the user best benefit from the system.

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