Commutative product semantics

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Abstract
This article describes a structured axiomatic theory in which important practical phenomena of product semantics can be described and analyzed. The approach includes and extends the well-known semiotic notions of icon, symbol and index. Several small-scale case studies illustrate the theory.

Keywords:
Product Semantics, Semiotics, Axiomatics.

1 Introduction
The goal pursued in this article is to have a structured axiomatic theory in which important practical phenomena of product semantics can be described and analyzed. It is well possible that this goal is too ambitious. One could compare it with the axioms of probability theory: since probability means coping with uncertainty, one could question whether it is possible at all to have an axiomatic basis for it. Kolmogorov did it nevertheless, in 1933. His theory does not predict the outcomes of all uncertain events in this world, but yet is a most valuable tool for developing practical tools and theories. For product semantics there is no such theory yet; I just have this vision and I can show how far I could get so far. The advantage of this kind of theory is that it will give rise to new tools, notably semantic tools.

This article is structured as follows. We begin with a very simple example (this section). Section 2 discusses language as a system. Next we identify the main notions to be described (Section 3). Then we introduce an axiom scheme (Section 4). After that we present several small-scale case studies to illustrate the theory (Sections 5, 6 and 7). In a final section we give a few concluding remarks. The article is written compactly with a focus on the examples and the formalization. For extensive introductions to the encompassing fields we refer to the other article submitted by the same author for this volume called Layers of Meaning. For a general introduction to product semantics we refer to e.g. Krippendorff [1]. For a general introduction to semiotics (the theory of signs) we refer to Chandler [2].

The approach we shall present is called commuting product semantics because of the specific approach of bringing structure into semantic insights and relationships In its purest form the approach amounts to drawing so-called commuting diagrams. The approach bears resemblance to the French structuralist approach to language. The work is open-ended and the underlying theory unfinished, but I see no better way to develop the theory than trying to push the approach as far as possible while doing case studies. It is equally valid to interpret commuting as traveling back and forth, emphasizing the dynamic nature of product semantics. The meaning of designed artifacts is how they are used,

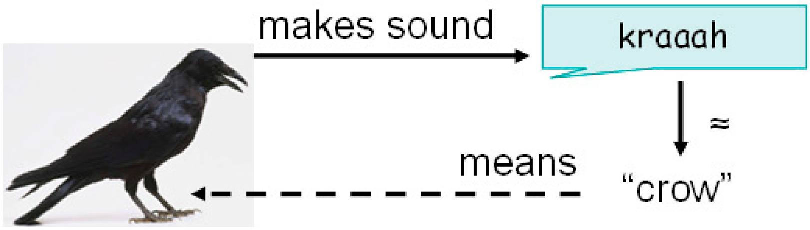

Fig. 1. Onomatopoeia as a commuting diagram.

how they change other things, how they are moved, and how they move people, how the meanings move back and forth. The approach rests on the idea that the meaning of a product always goes back to some fact which has occurred in the past, may occur in the future, or which may occur elsewhere.

The very first example comes from natural language semantics, It is about a so-called onomatopoeia. For example consider the familiar black bird calling "kraaaah" (an audio-book would serve my purpose better here, but let me assume this description also works). If I say the word "crow" I refer to such a bird. When I say the word, usually there is no crow and we can conveniently talk about crows whenever and wherever we want. Of course I may be with a child, see the bird and say "look Tommy, that's a crow", but this is not the easiest everyday use. This involves already the more complicated processes of teaching and learning.

Fig. 1 illustrates how the wrod "crow" got its meaning by means of a commuting diagram. The dashed arrow in Fig. 1 shows how the word "crow" has its usual meaning. It is derived from the other path of arrows which came into existence first. The arrow labeled ≈ denotes resemblance or similarity.

The situation is in fact already more complicated than suggested by the diagram. Not only the crow usually is not present when we mention it, the real crow we refer to usually is not calling at all at that moment. It is the bird, or a bird of this species, whose members in the past used to make that sound.

The right part of the diagram could be said to belong to a syntactic domain, the left part to a semantic domain. Just to avoid unnecessary confusion, there is a difference between linguistics and product semantics: in the above example, we looked for the meaning of a word and the meaning turned out to be a creature in 3D (the bird). In product semantics it often works the other way around: the syntactic domain is populated with 3D objects and the semantic domain is filled with other real-word matters, but in writings or diagrams they are shown as representations, often words.

Should we always go through such elaborate analysis before we can even use the simplest word? No, of course not, but yet this is the essence of how the bird got its name. Linguists analyze such matters. They invent terms such as "onomatopoeia" for useful linguistic patterns and study the usage of language by different authors and the usage of language in different communities. They look for commonalities and differences between languages and they study language evolution. They create dictionaries and grammar books and thus help society to have a culturally rich and economically successful use of language. The same can be done and should be done for the language of designed artifacts.

2 Language as a system

A language is a system. One cannot study a language by studying the syntactical elements and their meaning one by one. The most interesting phenomena happen because of relationships, similarities and differences between words. For the case of natural language this has been clearly recognized and exploited by the French structuralists such as De Saussure (1857-1913), Greimas (1917-1992), Derrida (1930-2004), the American linguist Chomsky (1928-), and semiotic scholars such as Eco (1932-). The relationships, similarities and differences between words arise because of the ease and frequency of replication and change, enriched with processes of resolving ambiguity, learning and teaching. Similar system aspects exist in biology (but until recently there was not much design freedom in biology) and in architecture (although the replication takes more effort in architecture). Similar aspects exist in industrial design too, which is what this paper is about.

Language is not static but dynamic. Although one can find books and lessons that describe for example English as a language with a given set of words and rules, the language is always changing and evolving. New words are being added and olds words forgotten. Old grammatical principles are violated, neglected and eventually removed from the language. To teach English at elementary schools, the static view is very useful. But for linguists at a university level, the dynamic view is indispensible and also is much more interesting. The same holds for product semantics. For daily usage it is very useful to know specific objects and how to use them. But for designers in higher design schools, the dynamic view is indispensible and again more interesting. Semiotic scholars describe the distinction between such dynamic and static aspects by the terms:

• first usage, and
• second usage.

Or, according to Eco [5], ratio difficilis (RD) and ratio facilis (RF). First usage is just to find or invent a new piece of syntax for something, invent it on the spot and speak it or make it or interpret something in a certain way, either deliberately or spontaneously. Second usage comes after that, re-using the same sign over and over again. What makes first usage difficult (difficilis means difficult) is to get the new sign into people's memory so it can be used and understood by many. Memory is essential for language and for product semantics. It includes both personal memory and institutional memory. The personal memory resides mostly in one's brain, but perhaps also partly in other areas of the sensor-motor system. The institutional memory resides in books, in the rules of schools and courts, and so on.

3 Notions to be described

Reading an object means to perceive a given object and then think of something else and act accordingly. The association from the given object to this "something else" is called meaning and is depicted by the dashed arrows as we did in the example of the crow. The arising of a meaning is conditioned by the existent set of moves (often depicted with the help of arrows). The moves include physical moves, memorized meanings, similarities and oppositions. Example, a door can be opened, "crow" means this type of big black bird, "crow" is similar to "kraaah" and rich is opposed to poor. Such moves (arrows) form a network around any given object, like a mind-map. If there is a chain of arrows and opposite arrows from a given object A to another, say B, then this chain yields a candidate meaning from A to B. The meaning which arises in reality is one of those candidate meanings, selected through a personal competitive process, partially unconscious, in which attention, emotional weight, and strength of memory connections play a role. Useful meanings tend to get standardized but only after a selection in a societal competitive process where the practicalities of language usage and the power of the various persons and institutions determine which meanings survive and which ones do not.

So these are the ingredients to be described: First, there are objects. These may include everyday objects, people, animals, people, images, words, sentences, concepts of culture and science, instruments, behaviors, and emotions. Next, there are moves. In the simplest case the move goes from an object to an object. Refinements such as contexts, multiple-input arrows and symmetric relationships between objects could be considered too (later). The moves represent the real or imagined changes that occur to objects during manufacturing, during usage, either in reality or in possibility. Also included are established meanings, similarities and oppositions. The term move should not be taken too literally: in some situations the term denotation or sign would have been more appropriate.

With these ingredients we have two describe the processes of using meaning arrows, notably ratio facilis (from now on abbreviated as RF) and ratio difficilis (from now on abbreviated as RD), the former being executed by a person, the latter usually by a society. These processes have the emergent effect that people develop shared understandings of objects, which will greatly benefit communication. The latter view is in line with the communication-oriented view on product semantics, as expressed amongst others by Crilly et al. [3].

4 Axiom scheme

The notions to be described can be cast into the form of ten rules, some of which are just introductions of a notion (a set of assumed objects), others being proper rules. The first seven rules are completely formal. Although the rules are very precise this does not mean they are already easily applicable. For that we would need to have the assumed notions (sets of objects), moves, utility function etc. at our disposition. Rules 8, 9 and 10 are less formal, they embody the transition to another paradigm than formal rules (perhaps an economic model). Rules 1-7 describe RF, rules 8 -10 describe RD.

1. There are objects. For objects think of everyday objects, technical artifacts, objects ready-to-hand (zuhanden, Heidegger's and Dourish' terminology), objects present-at-hand (vorhanden), but also plants, animals, words, icons, symbols, traces, finite-state-machines etcetera.

2. There are moves. Each move consists of an object called the source, an object called the destination, and an optional label. We write A $\rightarrow$ B if there is a move with objects A and B. The moves can represent the changes that occur to objects during manufacturing and during usage, either in reality or in possibility. Also included are established meanings, similarities and oppositions.

Intermezzo: For moves, think of moves through time and space, but also of all kinds of other associations. Moves also represent the semiotic concept of sign, which comprises both the signifiant and signifié (using De Saussure's terminology. We refer to (Chandler 2002) pages 83-85 for an introduction to De Saussure's terminology.

3. There are labels which can be associated with moves and which serve to classify moves. We write A $\rightarrow_L$ B for an arbitrary label L. The set of labels includes 1 for identity, φ for physics, μ for memory, $\subset$ for part-of, $\approx$ for similarity, $\neq$ for opposition, and α for voluntary human action. The labels are closed under composition, written as xy for labels x and y, and under inverse, written as x-1 for label x. Note that we do not equate for example x-1x and 1.

4. For a given set of moves, its closure is the smallest set of moves which includes the given set and satisfies the three rules:
   a. for all objects A we have A $\rightarrow_1$ A,
   b. for all A and B we have A $\rightarrow_x$ B implies B $\rightarrow_{x-1}$ A,
   c. A $\rightarrow_x$ B and B $\rightarrow_y$ C imply A $\rightarrow_{xy}$ C.

Intermezzo: the labels carry the origin or the reasoning why A means B. Now we use Greek letters and mathematical symbols, but later, for example after semantic tools will have been developed, the Greek letters can be replaced by more convenient symbols, colors, or interactions. A body of knowledge is represented by a set of moves. A pattern is a set of labels, for example $\{\mu\subset\}$ which we call "pars-pro-toto".[1] The closure of a given set of moves can be restricted by a pattern which means that we keep only those moves whose label is in the pattern. Patterns are interesting because each individual may have his or her own patterns. Moreover, from a scholarly point of view it is interesting to restrict a study to specific patterns only, like the natural language scholars who study patterns such as onomatopoeia, homonym, synonym, causative etc.

5. Given an object A and a set of moves M, we call a candidate meaning any move A $\rightarrow$ B which is in the closure of M.

6. For a given set of candidate meanings, a utility function is a function u assigning a number between 0 and 1 to each candidate meaning such that the sum of these numbers equals 1. The numbers are called utilities. Given an A, M and u, any B for which A $\rightarrow$ B is a candidate meaning with maximal utility is called a meaning of A.

7. A semantic event consists of a context, which is a triple (A, M, u), and an outcome which is a human action. More precisely, the outcome must be a move with the same source A and destination B as the meaning of A (or one of the meanings of A). The outcome must be labeled α, for human action.

Intermezzo. A semantic event occurs in the life of an individual i who sees an A and decides to interpret it as B because his knowledge of the world and his symbolic memory, all of which are represented by the closure of a personal set of moves Mi, lead him to the interpretation. The utility ui reflects the internal competition inside i among candidate meanings. The competing candidate meanings differ in memory strength, priming, emotional relevance, psychological repression, plausibility of the reasoning chain, etc. The utility thus depends both on the practical situation and the emotional state of the individual, all of which are not formally detailed except through the assumed utility function.

[1] If memory (μ) gives meaning to (Dutch) "groene baretten" namely (real) green barets, and if green barets are part of ($\subset$) of a specific type of soldiers then the pars-pro-toto pattern is why "groene baretten" refers to such soldiers.

The previous axioms all dealt with one person reading the object. But next we must also assume that there are others who shall observe such an outcome. Others may notice that i acts, but the relabeling to α models the fact that they cannot see his or her associations or reasoning chain. In the development of a society there is a common understanding of the world and a common symbolic code, some elements of which are given a more formal status through schools, laws, books, television shows, court rooms, group discussions, exercises, examinations and social rules. All of that will be summarized by the term school, which clearly should not be taken too literally. Depending on the case study one could consider giving the school a special status in the model but in other cases we may prefer Axelrod's idea of no central authority [4].

8. One way for individual i to adapt is to increase his or her understanding of the principles of physics and add a move $A \rightarrow_{\varphi} B$ to his or her personal set Mi . Alternatively he or she can just learn a move without specific understanding, adding $A \rightarrow_{\mu} B$. We call such additions learning. Forgetting is also possible. Forgetting is the removal of a move.

9. A semantic interaction consists of a semantic event followed by changes which add or reinforce certain meanings and remove or weaken others. Individuals thus learn. Reward and punishment often play a role. The semantic interactions involve multiple persons or one person and a school.

10. Semantic interactions may have the effect that many individuals share memorized moves $A \rightarrow_{\mu} B$, which will greatly benefit communication.

Intermezzo: The production and observation of meanings is a dynamic social process. The dynamic social process allows for innovation and at the same time maintains large commonalities in interpretation. Stability of the commonalities becomes an emerging phenomenon. Assume that individual i holds the move $A \rightarrow_{\mu} B$. But assume individual j holds that $A \rightarrow_{\mu} B'$. We consider some typical cases, for example, B = B' in which case nothing happens. Otherwise, assume B differs from B' and that j has a higher ranking authority than i and thus person i may learn that $A \rightarrow_{\mu} B'$. The repeated application of rules 8, 9 and 10 constitutes a process RD in which such updates happen regularly. But under normal circumstances, on average they will happen with a lower frequency than the application of the RF rules 1 - 7. The details of such an RD process are not formally modeled further in this paper. We leave them as an option for further research.

Pleasant and unpleasant experiences are drivers for learning and unlearning. Pain and fines are unpleasant. For example, interpreting a red traffic sign (A) as a cue to drive forward (B') instead of stop (B) could lead to a crash (the other driver representing the school) or a fine (the police officer representing the school). In this example, there is not even a candidate meaning of type $A \rightarrow B'$ in M_j so the police officer j punishes. Next time i acts according to $A \rightarrow B$.

Typically an interpretation which works out in practice is considered a positive reinforcement, like in Wittgenstein's language games, when the builder j says "brick" (A) and the assistant i is choosing between giving him a brick (B) or giving him a slab (B'). Delivering a brick, that is, $A \rightarrow_{\alpha} B$ will work out well. But an uninformed assistant i with $A \rightarrow_{\mu} B'$ perhaps takes $A \rightarrow_{\alpha} B'$, and thus runs the risk of being stormed at by the builder. The first builder to work this way probably had a competitive advantage over other builders, which gave him even more social power and allowed him to form a school by training assistants.

5 Icon, Symbol and Index

The traditional concepts of symbol, icon and index as proposed by Peirce appear as special cases of simple commuting diagrams, as shown in Fig. 2 (images from wikipedia/commons). We refer to (Chandler 2002) page 36 and 37 for an introduction.

The no-parking sign is a symbol. It must be learned by memory. Once one knows it, the candidate meaning "no parking" will pop-up upon seeing the sign. The dashed arrow in the diagram indicates this candidate meaning. The left hand side woman image is an icon. For an icon, there must be a physical or perceptive similarity. The concept index is illustrated by the specific concept of trace. The meteor makes a crater by the physical move of impact. Later, the crater means: there was a meteor.

Fig. 2: Examples of signs (symbol, icon and index).

6 Example

In many cases, moves represent changes of a state of affairs over time, as the next example demonstrates. Consider the type of chain closing shown in Fig. 3.

Fig. 3: Chain closing.

What does it mean? Well, the first meaning is what one can do with it. Hook the last bead into the closing and the chain remains closed, even under the force of slight pulling. It can be opened again by lifting the last bead and pulling. These moves, to be executed by the user are one type of meaning. This is depicted in Fig. 4.

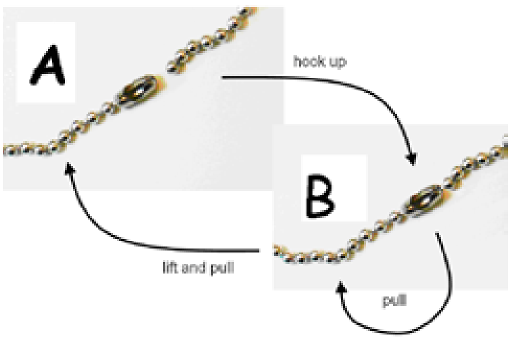

Fig. 4: Moves of chain closing.

So here the moves are what the user does and then the semantic arrow, pointing from the object to its meaning is given by the dashed arrow in the following composite diagram. Computer scientists would recognize the right-hand side structure as a finite state machine (FSM). This is shown in Fig. 5.

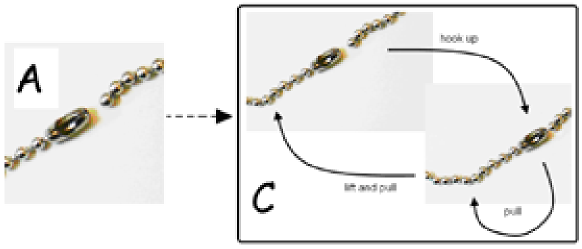

Fig. 5: Finite state machine meaning of chain closing.

The closing also has other meanings. This is a cheap kind of closing, which appears cheap for several reasons. These reasons can be understood in terms of moves as well. The first move occurred in the past: it is the manufacturing of the closing. A simple piece of plate metal, cut into a butterfly shape is folded and deformed, a not too difficult manufacturing step, easily imagined and doable by a fully automated machine. Now the meaning of the closing is the opposite of that move, as depicted in Fig. 6. The closing means "something made of plate metal".

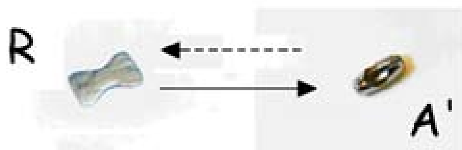

Fig. 6: Manufacturing meaning of chain closing.

The next move we like to discuss occurs in future, or at least, one easily imagines this to happen in future. When pulled heavily, the folded plate metal of the closing bends open and the bead gets out of the closing, which is now broken. This then is one meaning of the closing, that it is a thing which easily gets broken. The meaning (dashed arrow) goes parallel to the physical move. The example illustrates an important idea already mentioned: many meanings arise because of situations which have occurred in the past or situations which might occur in future. An object just being sensed in the present moment, here and now, without any interpretation is not semantically active (perhaps we should say that observer is not semantically active). But otherwise, the object is "saying" things which are not true; at least not true here and now. This is usually not wrong, like when someone is telling deliberate lies with wrong intentions. The idea expressed in Fig. 7 is that objects refer to other objects not here, other situations (not here, or not now), dangerous situations (hopefully never), and desirable situations (hopefully soon).

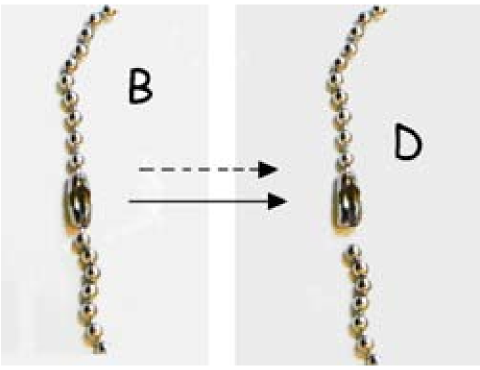

Fig. 7: Failure meaning of chain closing.

How does all of this appear formally? We have $A \rightarrow \varphi\ B$, the physical move to close the object. And $B \rightarrow \varphi\ A$ by lift and pull, next to $B \rightarrow \varphi\ B$ by pull. The move $A \rightarrow \mu\ C$ models that one knows that the device affords repeated close, pull and open behavior. The move $R \rightarrow \varphi\ A'$ described the physical possibility of folding a butterfly-formed piece of sheet metal to get something similar to the main body of the device. The inverse of the latter move is $A' \rightarrow \varphi_{-1}\ R$ which is a candidate meaning, viz. the meaning that A' is made from sheet metal indeed. It could have been made by casting melted metal, but I consider that very unlikely (low utility). Therefore I express my opinion that it is made from sheet metal. Expressing this in public is an act by me, so now $A' \rightarrow \alpha\ R$. This is a semantic event. Perhaps my act is wrong and I could be blamed for it by a manufacturing expert, which would be a semantic interaction. I know sheet metal is cheap, $R \rightarrow \mu$ cheap. The main body is a part of the chain itself, that is $A' \rightarrow \subset A$. Combining $A \rightarrow A'$ with $A' \rightarrow R$ and $R \rightarrow$ cheap a new candidate meaning emerges, viz. $A \rightarrow$ cheap. It has the label $\subset^{-1}\varphi^{-1}\mu$, which is a kind of formal code of the underlying reasoning. Yet-another candidate meaning is that, under load, physics implies that the device breaks up, $B \rightarrow \varphi\ D$.

7 Another example

We present the commuting diagram in Fig. 8 concerning the way in which the meaning arises for two of the signs on a Nokia phone 63101 (the model called "Triton" and other models launched around 2002).

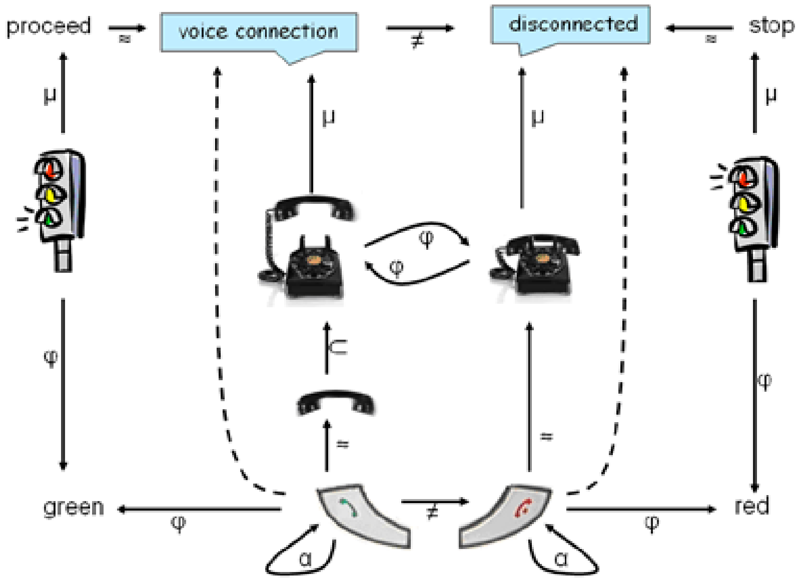

Fig. 8: Commuting diagram of Nokia phone signs.

Different manufacturers use subtly different signs to indicate similar meaning, for example Philips DECT phones have just the hook, either green or red. The hook is either upside or downside, and the relict of the old phone body is gone. See Fig. 9 (image adapted from Wikimedia commons). The physical movement between an onhook and off-hook phone must have been assumed to be a rotation of the hook in space, rather than the separation of the hook and the phone body.

7 Concluding remarks

The proposed axiom system forms a solid basis for studying specific aspects of product semantics and doing case studies. Rules 1 - 4 cover aspects belonging to the physical world and also belonging to part of the psychological domain: perception, action and memory. These rules do not rely on a mind-body dualism. On the contrary, Rules 1 - 4 address notions which are in the intersection of Newton's world (the laws of physics) and

Fig. 9: Different Philips DECT phone signs.

Freud's world (what's in a man's mind). Rules 1 - 4 not even have negation and allow for candidate meanings through chains of association. This is intentionally so to model the associative nature of the human mind.

In more refined case studies it may be necessary to extend the set of labels. Next to φ for physical action and μ for memory there may be more subtle labels in-between, like φ_1 for physics according to present-day university-level physics, φ_2 for physics as observed in daily life, and φ_3 for physics as assumed in a user's mind. Similarly, user actions α could be subdivided into actions for distinct persons. The utility function involves emotions, priming, taboos, and human values, which are best not addressed axiomatically but by the tools of the psychologists. Sensory pleasure and bodily pain can be added as objects, but this is near the boundary of the approach.

We mention two limitations of the formalism presented so-far, which probably can be addressed quite well by future extensions of the formalism. First limitation is the notion of context. Context is essential and many meanings are context-dependent. The meaning of a screw-driver becomes relevant when there are screws and things to screw in. Technically, the context can be added to the moves, perhaps as in formal logic, writing $C \vdash A \rightarrow B$ when C is a context. In formal diagrams and in tools, the context can be depicted as a background or at a given position in a pictorial composition scheme. The second limitation is mediation. Certain objects behave as carriers, media or tools. They transform the spatial, temporal and physical qualities of other objects. The function concept from mathematics, could be helpful for mediation. The axiom system entails the possibility of developing semantic design tools.

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