A Formal Approach to Product Semantics with an Application to Sustainable Design

Loe Feijs and Frithjof Meinel

1. Introduction

Product semantics is important because it can make the difference between commercial success and failure. We propose a formal framework that is rooted in the theory of signs but, at the same time, is practical and directly applicable. Product semantics is essential in the design of products that must be easy, safe, efficient, and pleasurable to use. It is not easy to read the meaning of a given thing because the meaning may depend on the context in which the thing is shown, next to the cultural and personal background of the maker and the reader. For the formal framework, we borrow concepts from semiotics (the theory of signs), and denotational semantics, a branch of computer science studying the meanings of computer artifacts such as programs. Another innovation is our use of pictures in which we freely mix formulas and images.

The scope of the framework developed thus far includes the classical design of physical products such as furniture and vehicles. We have not yet covered designs that are of a more virtual nature, such as Web design or brand design. The framework is capable of dealing with messages of a personal or ideological nature. The area of sustainable design is included, which is important in view of its societal relevance. We do not go into the complexities of postmodern semiotics including, for example, the phenomenon noted by Baudrillard that signs tend to be consumed in a cyclic way and refer to a simulated world.

2. Formal Framework

2.1 Meaning Functions for Signs

The sources of our modeling concepts are Shannon's theory of information and communication,[1] Pierce's theory of signs,[2] Eco's semiotics,[3] and denotational semantics.[4]

Eco proposes the term "s-code" for a set of signals or notions ruled by internal combinatory laws. A "code" is a rule coupling the items of one s-code with the items of another. Thus, a code establishes the correlation of an expression plane with a content plane. Sometimes the correlation behaves like a function in the mathematical sense, like the square function mapping 1 to 1, 2 to 4, 3 to 9, etc.

1 See Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27 (July and October 1948): 379–423 and 623–656.

2 See Daniel Chandler, *Semiotics, the Basics* (London: Routledge, 2003). The original reference to Pierce is *Collected Papers of Charles Sanders Peirce,* 8 vols., Charles Hartshorne, Paul Weiss, and Arthur Burks, eds. (Cambridge, MA: Harvard University Press, 1931–1958).

3 See Umberto Eco, *A Theory of Semiotics* (Bloomington: Indiana University Press, 1979).

4 Michael J. C. Gordon, *The Denotational Description of Programming Languages: An Introduction* (New York: Springer-Verlag, 1979)

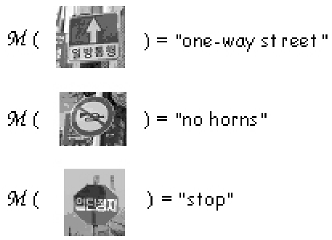


Figure 1
Meaning function with s-code of traffic signs as domain.

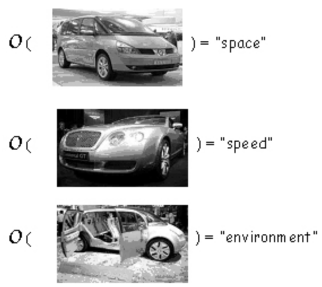


Figure 2
Meaning function about car forms and what they are optimized for.

Eco calls it a "sign-function." In mathematics, when f is a function, one writes, for example, $f(1) = 1$, $f(2) = 4$, and $f(3) = 9$. In computer science, one calls it a "meaning function." In figure 1, this notation is used for a meaning function: *M,* whose domain is an s-code of traffic signs and whose range is another s-code, strings in English. In semiotics: a *sign* is a pair consisting of an s-code (a traffic sign) and the corresponding meaning (for example "one-way street").

Eco mostly deals with texts, but physical products work as signs, too. In Bürdek's work[5] the sign functions of products are treated in Chapters 15 and 16. Dormer[6] gives a survey of goals for which product semantics can be used: follow function, fashion, self-explanatory design, etc. Krippendorff & Butter[7] is another classic.

2.2 Meaning Functions for Products

According to Eco, the meaning of a sign is a cultural unit, not the physical thing. What are the meanings of the products, systems, and services designed by industrial designers? In Eco's terms, what are the semantic fields and how are they structured? The answer depends on the product type and the culture in which it is interpreted. The traffic sign is a traditional sign, but now we can demonstrate that it also is possible to put real products in place of these signs. Figure 2 shows three existing products belonging to the s-code "car forms" and the meaning function *O,* mapping to the semantic field "what the car is optimized for."

Similar examples can be given for other aspects of cars, syntactically considering color, form, and material, as well as other aspects of the semantic field such as emotions, associations, price expectations, buyer profiles, etc. Until now, color, form, material, and texture have been the main constituents of the s-codes for industrial designers (next to engineering aspects). It will be necessary to add behavior to s-codes, too.[8]

2.3 Semantic Fields

In this section, we develop a formal view on meanings. If P is a set of products (designs) and S a semantic field, a meaning function is a function $M : P9 \rightarrow S$. For example, consider the traffic signs of figure 1 again. Here, P is the set of traffic signs (see figure 3) where we add a pair of brackets { and } to indicate a set. S is a set of commands about desired behavior on the street: P = {"one-way street," "no horns," "stop," etc.}. The latter set is called the semantic field (Eco's terminology). But other products are more complicated than traffic signs. Even when not created as a sign in the first place, it is inevitable that any product becomes a sign. It emits messages about its function, its intended use, its owner, etc. The question we address next is: What are these messages? or, more general, *What are these semantic fields?* If we adopt the terminology that product p emits

5 See Bernhard E. Bürdek, Design, *Geschiedenis, theorie en praktijk van de productontwikkeling,* (Deu Haag: Ten Hagen Stam,1991, German version; 1996, Dutch version).
6 See Peter Dormer, *The Meanings of Modern Design* (London: Thames and Hudson, 1990).
7 Klaus Krippendorff and Reinhart Butter, "Product Semantics: Exploring the Symbolic Qualities of Form," *Innovation, Journal of the Industrial Designers Society of America* 3:2 (1984): 4–9.
8 Loe Feijs and Kees Overbeeke, "Design Science: Meaning, Action, and Value" (Presented at the Sixth Asian Design Internaional Conference; Tsukoba, Japan, 2003).

Figure 3
Defining the domain of a meaning function as a set.

message *s* whenever $M(p) = s$, we must ask what these messages are. According to Eco, the elements of a semantic field are "cultural units" (not necessarily words, things, or facts). The definition of semantic fields is not without problems.[9]

2.4 Multiple Meaning Functions

We allow for several semantic fields. Each semantic field is concerned with one aspect of the object of design. We approximate the complexities of semantic fields by a Cartesian, coordinate-wise approach. We always can add other aspects later on.

To illustrate the concept of multiple meaning functions, each mapping to a different semantic field, we again take traffic signs as products. The first semantic field is a set of commands $S1$= {"one-way-street," "no horns," "stop," etc.}. The second semantic field is a set of countries, $S2$= {"Korea," "England," "The Netherlands," etc.}. So we have two meaning functions $M1 : P \rightarrow S1$, that tells the command, and $M2 : P \rightarrow S2$, that tells the country where the traffic sign appears. Thus,

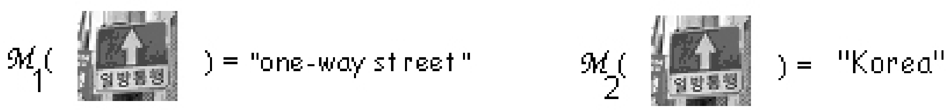


Figure 4
Equations for two distinct meaning functions.

Compositionality is the idea that a composite object's meaning can be understood by taking the meanings of the constituent parts and combining them in a way that is typical for the object type at hand. For really complex objects, compositionality is a way of handling complexity. In some cases, the notion of "Gestalt" or archetype is indispensable. In other cases, the composition works on the basis of features. Referring to the second car of figure 2, the conclusion that this car is optimized for speed need not be obtained by a general impression of its "gestalt" or its "archetype," nor is it necessary to examine *all* details of its construction. The outcome of the function O that tells what the car is optimized for can be derived by considering three details: the size of the motor compartment, the presence of cooling fans on the brakes, and the size of the headlights (see figure 5).

9 See Umberto Eco, *A Theory of Semiotics* (Bloomington: Indiana University Press, 1979), 80 for a survey.

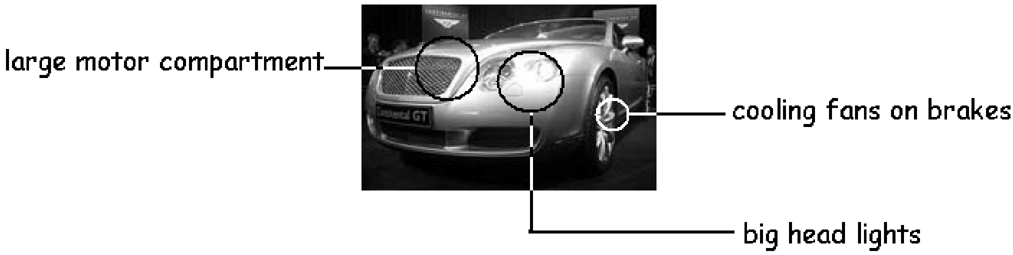


Figure 5
Car details telling what the car is optimized for.

Consider O as a mathematical function of three arguments, say a_1, a_2, and a_3 (motor compartment, brake fans, headlights, respectively). For simplicity, let the arguments be Boolean values (false or true) such that for a_1, *false* means "not a large motor compartment" and *true* means "large motor compartment," etc. We can write down defining equations for O.

O (true, true, true) = "speed"
O (true, false, true) = "speed"
O (true, true, false) = "speed"
O (false, X, Y) ≠ "speed"

In other words, for the car to express that it is optimized for speed, it is necessary to have a large motor compartment. If it has a large motor compartment and at least one of the other characteristics, then it is optimized for speed. Although this is not a complete set of defining equations, it gives the general idea.

2.5 Mechanisms of Sign Production

The following distinction of signs is due to Pierce: symbols, icons, and indices. A "symbol" is a sign based on convention—it must be learned. An example is the "no parking" traffic sign (see figure 6). An "icon" resembles the thing it stands for. For example, the icon of figure 6 (right), denotes a CD drive. An "index" has a physical connection to the thing it means, or carries an imprint of its meaning (smoke is a sign of fire, an open door is a sign that someone is home, footprints are a sign someone has passed by).

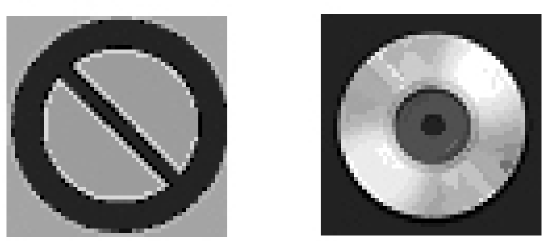


Figure 6
Example of a symbol ("no parking") and an icon (CD drive).

Eco has laid a basis for a theory of sign production. He considers three linked processes: (1) the process of shaping the expression-continuum; (2) the process of correlating that shaped continuum with its possible content; and (3) the process of connecting these signs to factual events, things, or states of the world. He writes: "Some signs seem better adapted to the expression of abstract correlations (like symbols), and others that would appear to be more useful in direct reference to states of the word, icons, or indices are more immediately involved in the direct mentioning of actual objects." In our case, the situation is reversed: the material features of designed objects such as a chair or a bicycle serve as signs. These material signs refer to states of the world, sometimes in a direct, technical sense, sometimes conveying abstract ideas.

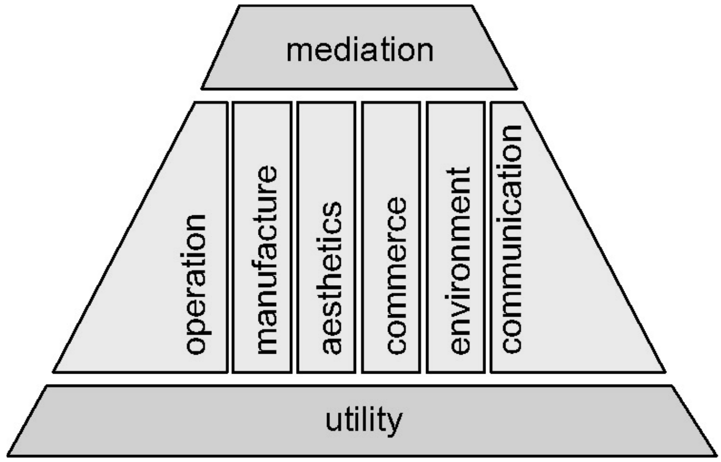
Eco distinguishes between two types of sign production: *ratio facilis* (reusing an existing sign by replication) and *ratio difficilis* (creating a new sign). Conventions, similarities, analogies, examples, and imprints play a role in creating new signs. Design includes *ratio difficilis* since designers create new forms, meanings, and values which, once known, become part of human culture and hence a part of codes. But there also is a lot of *ratio facilis* in design, since the existing codes to a large extent determine how users understand a product. If all signs carried by new products would be invented from scratch, users would have difficulty in recognizing and operating the products.

3. Focusing the Framework

So far, we do not have a classification of semantic fields. Let us assume that most messages are of a predicative nature: the message asserts a property or a fact about a certain subject. If we say "My sister is a painter," then "My sister" is the subject and "is a painter" is the predicate. Sentences such as "My sister is a painter" need not be true: perhaps my real sister is a scientist. This is not a defect of the sign system. On the contrary, according to Eco, it is essential that signs can be used to lie (this also holds for Tarski's truth in logic). The subject-predicate structure helps to classify the semantic fields. We classify them by subject, asking "What is the message about?" It can be about a concrete product function (e.g., "This chair is comfortable.") but also about something more abstract ("The user of this bicycle is sportsman-like.").

One of the first classifications of product functions is the architectural theory of Vitruvius (31 B.C.). He distinguished between *utilitas* (utility), *firmitas* (firmness, construction), and *venustas* (beauty, sign). As an adoption of Vitruvius's trinity, modern product functions include utility, operation, manufacture, commerce, and environment, etc. They must cover all aspects of a product that users and producers care about, and which concern the interests of society, too.

Figure 7
Layers of semantic fields.



We outline eight semantic fields, ranging from practical issues of product functions (utility, operation, manufacture, commerce, etc.) to the mediation of ideas about something else. The semantic fields are grouped into three layers. The relation between the layers is defined by dependence. The solution of the lower layer's functional problems is necessary for the higher layer messages to make sense. Thus, the higher layer is dependent on the lower layer. For a chair, for example, if nobody can sit on it, messages about manufacturing, commerce, etc. can hardly reach the audience. The layers of semantic fields are given in figure 7. The layers are:

• Utility: the essential basic function of the product.

• Extended functions: aspects that a designer has to address to make the product successful and operational including manufacture, environmental concerns, aesthetics, commerce, and communication.

• Mediation: this happens when the product is used to send messages about something else—not the product itself. In the extreme case, the product is a carrier of matter (a coffee cup) or of information (a television). For the electric bicycle case, we choose two semantic fields: the *user* and *sustainable development* itself.

The bottom layer of figure 7 marks the *utility function,* which defines the product by data such as power, size, or application range. Six further functions are arranged on top of *utility.* The *operational function* includes the user-product interface for physical and cognitive interaction. Ergonomic data and the adaptability to different users' needs are summarized in that function. The *manufacture function* tells about the mechanical structure, materials, and technologies. Furthermore, this category visualizes the tools used for designing the products—for instance, model-making technologies, computer software, and the ability to fit to other system components. The *aesthetic function* focuses on shapes, colors, and proportions. For interactive products, it also makes sense to speak of the aesthetics of the interaction. This leads us to the *commercial function.* Industrially produced products only make sense when they have the character of selling goods. All features and the selling price have to be attractive in the market to set a consume impulse. The *environmental function* sums up the effects to the natural and social environment—resource consumption, emission of unhealthy substances or disturbing noise, and visual pollution. It considers the whole product life cycle from development, manufacturing, use, and maintenance to reuse, recycling, biodegradation, etc. Finally, there is the *communication function.* It is best if the product is self-explanatory, and no extra communication functions have to be designed.

For the top layer of figure 7, we choose two semantic fields: the *user,* and *sustainable development* itself. We use the term mediation because the product is sending messages about something else, not the product itself. We motivate our choice next. We consider messages about the user because people use products to emit messages about themselves; a Mercedes tells about the user's wealth. Nice clothes make the user look young or attractive. Cars, clothes, chairs, and bicycles share the property that, considered as carriers, the user is the content. We consider messages about sustainable development for two reasons. One reason is that sustainable development is not only a technical problem, but also an awareness issue. The other reason is the role designers can play for sustainable development: to create propositions that help to envisage possible future worlds.[10] Writers, artists, and filmmakers create such visions, but the unique role of designers is to show what is possible, taking constraints related to manufacturing, environment, etc. into account. Or, as Marzano puts it, "Design is a political act. Every time we design a product, we are making a statement about the direction the world will move in." [11]

Sustainable development means designing products that do not exhaust the world's natural resources. That results in efficient usage of materials and energy, as well as a reduction in pollution. Other aspects such as product life cycle, recycling, and fair trade are important but outside the scope of the present article. The case study we did concerned an electric bicycle. Because its concept was related to sustainability, the aspects of efficient usage of energy and the reduction of pollution play an implicit role.

We use the classification of figure 7 for instantiating the framework of Sec. 2. First, the two lower layers. In principle, each product has several meaning functions: one for "utility" and one for each extended product function. If, for a certain product, some functions are uninteresting, we work with fewer meaning functions. We need semantic fields, called $S_{utility}$, $S_{operation}$, $S_{manufacture}$, and so on. The set $S_{utility}$, by definition, contains all possible messages about a product's utility. We also need several meaning functions, one for each semantic field. We call them $M_{utility}$, $M_{operation}$, etc. If P is a set of

10 See Ezio Manzini, *Visioni di mondi possibili e design* (Presentation at the Visions of Possible Worlds Conference, Triennale di Milano, Italy, November 28–29, 2003).

11 See Stefano Marzano, "Chocolate for Breakfast" (Keynote address to the 18th ICSID Congress, Glasgow, 1993), ICSID News (June 1993), International Council of Societies of Industrial Design, Helsinki.

products under consideration, then the input and output types of the meaning functions are $M_{utility} : P \rightarrow S_{utility}$ for the first meaning function, $M_{operation} : P \rightarrow S_{operation}$ for the second, etc.

In Sec. 4, we describe and analyze a concrete design: an electric bicycle. F. Meinel and P. Reinspieß, both professors of industrial design at the University of Art and Design Halle, designed it with a concern for sustainability. The analysis will be conducted as a case study of the formal framework focusing on the product semantics (not on the technical design). The semantics are based on the original designer's explanations, shedding light on the sign creation process (*ratio difficilis*). The intended semantics need not coincide with the user's readings; verifying intended and perceived semantics is outside the scope of this article.

4. Case Study

4.1 Product Description

In the discourse of sustainable mobility, the contradiction between cars and bicycles is often treated. While cars have a broad acceptance in society, bicycles normally are recognized as sports and leisure time appliances, but not as alternatives to individual motorized personal transport (although the situation differs per country; e.g., in the Netherlands, bicycles are more accepted as regular transportation means than in Germany). The aim of the development leading to the "e-bike" was to give the electrically supported city-bicycle its own expression, positioning it as an alternative to the car in urban transport. The first problem was to position the additional components such as motor and accumulators not in spaces where luggage normally is stored and carried. The second problem was to give the electrical power components a powerful meaning. This results in an arrangement of the components around the hub of the wheels.

The position of the electrical drive components near the hubs results

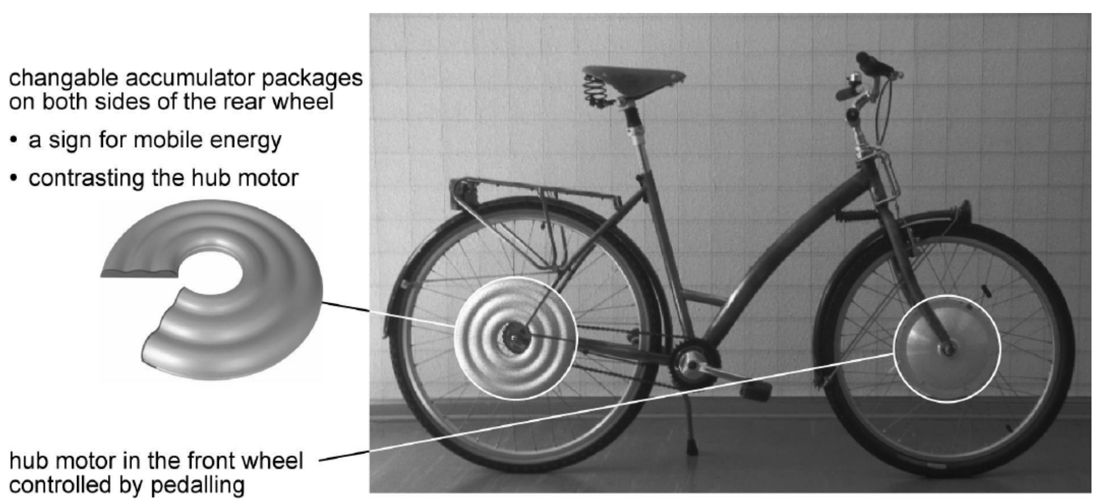


Figure 8
Arrangement of electrical power components.
Photo by F. Meinel, Halle, 2003.

Figure 9
The electric bicycle in action.
Photo by Th. Richter, Halle, 2003.

in a low center of gravity. This gives better comfort for city application, but has disadvantages in rural regions because of the unsprung suspension of the driving masses. The shape of the accumulator package should support the character of powerful object, visualized by concentric waves or a breathing image. This means charging and discharging of electrical energy, as well as recharging from the mains, and during accelerating and breaking, when energy is fed into the accumulator back. What is not visually perceivable is how the energy flow is controlled. The driver of this kind of bicycle will only be electrically supported while pedaling. The pedal force controls the hub motor so that muscle energy is effectively doubled. This feature is hard to visualize. The example shows the limited abilities of product design to code meanings in complex products using new control technologies and hidden drives. Virtual simulation techniques, instruction videos, or promotional tours are needed to convince potential costumers of the product's innovative qualities.

4.2. Formal Analysis of the Electric Bicycle Semantics

4.1 was written by one of the designers of the electric bicycle, the second author of this article, after an introduction to an earlier version of the formal framework. Sec. 4.1 reflects the original ideas of the electric bicycle designer concerning the messages he wanted to code, and how he did it. Sec. 4.1 is taken as a starting point; we give the explanations of Sec. 4.1 a place in the formal framework.

We describe the levels of meaning in a bottom-up fashion, working from a detail level towards the product level, where the meaning of the bicycle as a whole is at stake. At the lowest level, the product has "features," by which we mean technical details, style elements, material choices, or construction elements that are easily identified and recognized.[12] These features act as signs. Most features have a clear location in the bicycle's structure (we found this even more clearly in the chair case study). Other features, even when not pinpointed by location, are clearly recognizable properties. Each feature codes a simple message, usually a direct technical, economic, or ergonomic consequence of the feature. Therefore, we assume the existence of another meaning function C that maps features to simple messages (consequences). Let F be the set of features and C the set of possible technical, economic, or ergonomic consequences of features. We write $C : F \rightarrow C$ to express the input-output type of this meaning function. These consequences can be grouped in a natural way according to utility, manufacture, operation, and environment. The other three product functions are not considered in this case study (they are important, but the analysis is sufficiently interesting and complex without them). So we assume a grouping, assigning one of utility, manufacture, operation, environment to each feature. For example, if "comfortable" is a consequence, then this belongs to utility. The combined effect of the consequences for one product function is a message about that product function.

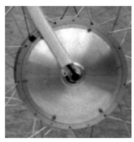
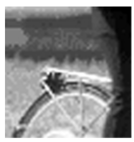
The product-level meaning functions such as $M_{utility} : P \rightarrow S_{utility}$ are understood as a three-step process; the product has features, the features have consequences, and the consequences belong to product functions. If there are several consequences for one product function, we must consider their combined effect. Since the product is an element of P, and since a message related to a product function (e.g., utility is an element of $S_{utility}$) we see that indeed we find a meaning function mapping from P to $S_{utility}$. Note the order: only after we have found the consequence of a feature we know to which product function it belongs.

For the set P of *products* under consideration, we consider all possible bicycles with auxiliary motors, either electric motors or small combustion engines. Still, this is not a proper mathematical definition of a set, but we prefer to be pragmatic in these matters.

The next question is: What are the *features* for this electric bicycle? The following table gives an overview. The first column shows the feature in a visual form, mostly taken from figure 8. The second column describes the feature in a text form. The text form is either a direct translation of the visual/tactile form, or otherwise it is based on the textual description and the explanation given in Sec. 4.1. For the time being, we treat the elements in the first column as

12 If F denotes the set of all products under consideration and F the set of features, then the fact that each product has a set of features can be expressed mathematically by assuming a function F from F to sets of features. As a formula, $F : P \rightarrow 2^F$. The notation $C : F \rightarrow C$ means that C is a function that gives a consequence for each feature.

a kind of synonym of the corresponding second-column element. The pictures of the rear luggage carrier and the open-frame structure above the front wheel serve as a visual of the feature "normal luggage space." This is based on the designer's remark that: "The first problem was to arrange the additional components like motor and accumulators not in spaces where luggage normally is stored and carried."

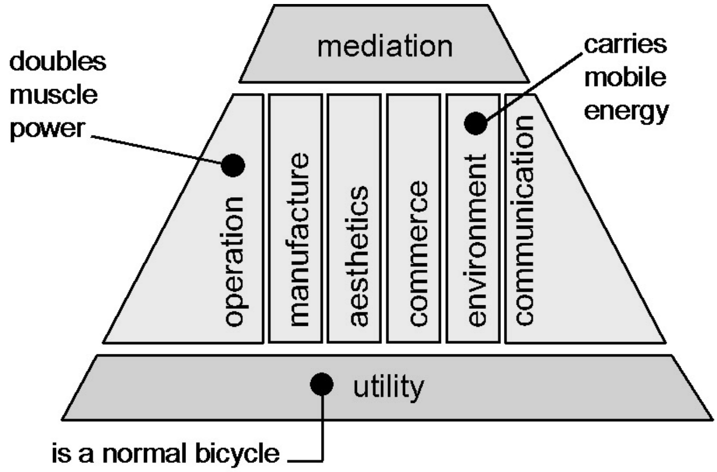
Sign (visual)	(textual)	Meaning
	Changeable accumulator package	This bicycle carries mobile energy
	Hub motor contrasting to the rear wheel accumulator package	This is a normal bicycle
 	Normal luggage space	This is a normal bicycle
	Pedal force controls the hub motor	This bicycle doubles muscle power

The first two columns give the result of the function *F* applied to the electric bicycle. As a formula: *F* (electric bicycle) = {changeable accu-pack, hub motor contrasting rear wheel accu-packs, normal luggage space, pedal force controls hub motor}. For the meaning function *C* that maps features to consequences, we have equations:

C (changeable accu-pack) = "carries mobile energy"
C (hub motor contrasting rear wheel accu-packs) = "is a normal bicycle"
C (normal luggage space) = "is a normal bicycle"
C (pedal force controls hub motor) = "doubles muscle power"

The grouping of the consequences is given in figure 10.

Figure 10
Product functions for the electric bicycle.



Finally, we discuss the top-level messages. The message this bicycle mediates about the user is "sportsmanship"—at least it does so much better than many other electric bicycles or mopeds. The message is told by the attractive balance in the bicycle's form. The message also is told by the fact that the electric bicycle doubles muscle power (the user still has to work the pedal). Concerning sustainable development, it is a statement that attractive electric bicycles can be developed that don't make the user appear weak.

4.3. Codes for Electric Bicycles

Now we set out to identify some of the codes of bicycle features. We need several tables, one for each position or function. We assume that bicycle functions have typical positions. For example, the function "storage" typically is positioned above one of the wheels.

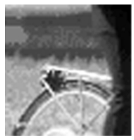
First, we deal with the changeable accumulator-package. What things should it be compared to? Its position is near the rear wheel's hub, which is where most motorized bicycles have their engine (although engines sometimes appear at other places, such as in the classical "Solex"). Bicycles usually have either brakes or gear-wheels at this position. It is a typical position for things related to transmitting power.

The code table is given below. The issue of hiding or not hiding technicalities is important. For the freewheel with derailleur, for example, the technicalities are not hidden, which makes the bicycle say that the user is sportsmanlike (this is an example of a mediated message). If the technicalities are hidden, as done by the chain cover, no sportsmanship is expressed at all. As soon as there is an engine, the situation is completely reversed. The small combustion engine reveals that the user lacks power to drive the bicycle on his or her own, so it tries to minimize the engine's visibility.[13] The electromotor already is better hidden. The changeable accumulator-package is quite distinct from the other signs in this code. Although the internals are hidden, no attempt has been made to make the accumulator-package itself invisible.

13 Note that, in this section, we discuss the traditional code. For the electric bicycle analyzed in this case study, we have attempted to work around the visibility issue. Instead of hiding the motor and the energy carrier completely (which usually fails), signs of balance and breathing have been introduced..

Sign (visual)	(textual)	Meaning
	Freewheel and derailleur	This is a bicycle with changeable gear-ration, showing technicalities.
	Chain cover	This is a normal bicycle, hiding technicalities
	Combustion engine	This bicycle has a moped engine
	Electromotor	This bicycle has an electromotor
	Changeable accumulator package	This bicycle carries mobile energy

Next, we deal with the luggage space. We compare it to the things that could otherwise occupy the typical luggage positions. Along the same lines, it is possible to set up a code table in which the hub-motor appears; in view of the size of the article, these are not included. The luggage space code table is below.

Sign (visual)	(textual)	Meaning
	Normal luggage space (front)	This is a normal bicycle
	Engine near front wheel	This bicycle has a small auxiliary motor above the front wheel
	Normal luggage space (rear)	This is a normal bicycle
	Tank near rear wheel	This bicycle has some unavoidable space-consuming storage device

4.4. Analysis of the Electric Bicycle Sign Production

In this section, we address the question: Where do the signs of the bicycle come from? The normal luggage space is an index. There is a direct physical connection with the luggage that fits. The hub motor resembles an electrical motor as known from similar electric bicycles, but it also somewhat resembles normal brakes. Together with the changeable accumulator-package, it gives the bicycle a certain balance. The sign of balance mainly emerges by contrast to other electric bicycles which are particularly heavy on one side, such as the “Spartamet” (rear) or the “Solex” (front).

The most intriguing sign is the changeable accumulator package. It is clearly a case of *ratio difficilis,* since it is an innovation into the code tables of bicycles. Whether it is understood and eventually becomes, by convention, an element of the common code tables for bicycles is another matter. Only the future can tell. The accumulator-package is meant to convey an abstract idea: that it can be charged and recharged. The source of the chosen form seems mostly based on a similarity with air-breathing objects. Examples are bellows, a harmonica, an inflatable chair, an air pump, a male torso (see figure 11).

Figure 11
Air-breathing objects as sources for the accumulator-package sign.

5. Concluding Remarks

The framework developed so far can be evaluated against the requirements formulated in Sec. 1. As the references and the examples show, the framework really is rooted in the theory of signs. It can deal with real designs and their physical elements, as demonstrated by the examples of figures 1–5 and by the case studies. The framework can deal with messages of a personal or ideological nature, too; modeled as a limited form of mediation. The framework is supposed to be usable as a tool for analyzing products. The case studies done by Feijs and Meinel confirm this expectation. Two chairs have been analyzed, including the STAX® of Compwood™ by Meinel and an electric bicycle by Meinel and Reinspieß. To limit the article's length, only the latter case study is discussed here.

Although we do not aim for completeness, we mention two alternative frameworks. Guenand and Capell Zapata[14] [Guenand et al.] investigated experimental methods to evaluate product semantics. Van Breemen et al.[15] developed a methodology for design for aesthetics. They set out to identify rules describing how physical attributes, composition, and shape express aesthetic characteristics.

Options for future work: Next to doing more case studies, it can be seen that the theoretic framework needs extensions for dealing with multisensory interaction. Some work in this direction already has been done by Feijs and Overbeeke[16] and Djajadingrat et al.[17] Another reason why the framework needs extension is that future products will be combined with complex services; some products could even be dematerialized by virtual technologies. This means that the study of semantics shifts to the system level.

Acknowledgments

The authors wish to thank Tom Djajadingrat and Kees Dorst for providing ueful comments on an earlier version of the manuscript.

14 See Anne Guenand and Feran Capell Zapata, *A Performance Aid in Creativity and Capitalization for Designers and Semiologists: A Reference System of Semantic Characterization of Products Based on an Ontology* (Presented at the Sixth Asian Design International Conference, Tsukuba, Japan, 2003).

15 See E. Van Breemen, I. Horvath, W. Knoop, J. Vergeest, and B. Pham, "Developing a Methodology for Design for Aesthetics Based on Analogy of Communication" (submitted to ASME '98 Design Theory and Methodology, http://dutoce.io.tudelft.nl/~jouke/docdb/docs/isatat_98_knoop.pdf.

16 See Loe Feijs and Kees Overbeeke, "Design Science: Meaning, Action, and Value" (Presented at the Sixth Asian Design International Conference, Tsukuba, Japan, 2003).

17 See J. P. Djajadiningrat, C. J. Overbeeke, and S. Wensveen, "But How, Donald, Tell Us How?" N. Macdonald, ed., in *Proceedings of DIS2002* (2002): 285–291.