Design Science: Meaning, Action and Value

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Abstract

In this position paper we sketch our view on a design science entrenched in the constituent parts of meaning, action and value, and their consequences. Our point of departure is that the notion of meaning is central to design: Design is about materializing meaning. To complicate things, the explosive development of technology in computing and tele-communication has seriously challenged the meaning issue. Products are no longer passive: they behave. And this behavior, touching the user's behavior, has to be designed. We base our view on Eco's approach to semantics. His central terms are translated into a message sequence chart model of a dialogue between user and product. This allows for these terms to be applied to this dialogic behavior, thus giving the initial impetus to a theoretical framework. This paper is our first trial for a comprehensive survey of our view on a design theory for high-tech, highly interactive, and thus behavioral, products. As such it is mainly based on philosophy and examples from design practice, education and research.

***Key words**: semantics, interaction, exploration, value, respect.*

1. Introduction

The structure of this paper is as follows. Section 2 is about meaning. For this we adopt a semiotic framework, using insights formulated by Pierce and Eco. Section. 3 is about interaction. In order to link interaction to meaning we adopt insights from philosophy, perception theory and a formal dialogue-based model that comes from computing science. After that we turn to values (Section 4) and we present examples (Section 5).

2. Meaning

Product semantics is related to semiotics, linguistics, anthropology and psychology. It is not easy to read "the meaning" of a given artifact, because the meaning may depend on the context in which the thing is shown, next to the cultural and personal background of the interpretant. Thus it is an intellectual challenge to understand the meaning of things. An even greater challenge is to create value by designing useful and meaningful products. Roughly speaking, the designer has to create value not only by creating useful functionality but also meanings that convey human values beyond functions; this is where ethics and humanistic values come in.

2.1 Meaning functions

Our point of departure is that the notion of meaning is central to design: Design is about materializing meaning. The study of meaning belongs to the field of semiotics [1,2], from which we use a number of concepts and notations. Eco [2] proposes the term *s-code* for a set of signals or notions ruled by internal combinatory laws. A *code* couples 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 of a prescriptive rule, like the square function mapping 1 to 1, 2 to 4, 3 to 9, etc. Eco calls it a sign-function. In mathematics, if f is a function, one writes for example $f(1) = 1$, $f(2) = 4$ and $f(3) = 9$. In computer science, where the semantics of computer programs are studied, one calls it a *meaning function*. In Figure 1 this notation is used for a meaning function $\mathcal{M}$ whose domain is an s-code of traffic signs and whose range is another s-code: strings in English. This example demonstrates a central concept in semiotics: a *sign* is a pair consisting of an s-code (a traffic sign) and the corresponding string (for example "one-way street"). The correspondence is given by the meaning function.

$\mathcal{M}$ () = "one-way street"

$\mathcal{M}$ () = "no horns"

$\mathcal{M}$ () = "stop"

Fig 1: Meaning function having an s-code of traffic signs as its domain.

The semantics of designed products and systems are much more complicated and therefore the concept of meaning function must be extended. The above-mentioned notational machinery is helpful to deal with the extensions one by one, without too much confusion. Some of these complications and extensions have been studied for quite some time in semiotics, product semantics, linguistics and computer science; they are not new, as such. This is not to suggest that the associated problems have been solved. But we want to distinguish them from a number of complications and extensions we want to draw the attention to in this paper because the latter are becoming increasingly urgent.

2.2 From color, form and material towards behavior

The semantics of behavior is urgent because of the developments in computing and tele-communication. Later, we address "value", but this has a dimension beyond meaning alone.

According to Eco, the meaning of a sign is a cultural unit, not the physical thing itself. Pierce's terminology allows for both the cultural unit ("interpretant") and the object itself. What are the meanings of the products, systems and services that are designed by Industrial Designers? In Eco's terms: what are the semantic fields and how are they structured? The answer depends on the type of product and the culture in which it is interpreted. Yet these are the questions that designers have dealt with in the past, explicitly, by studying design history and developing design theory, or implicitly by creating designs with interesting meanings. For the remainder of the article, let us pretend that these questions are being dealt with adequately for s-codes based on color, form and material. To illustrate this, Fig. 2

shows 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".

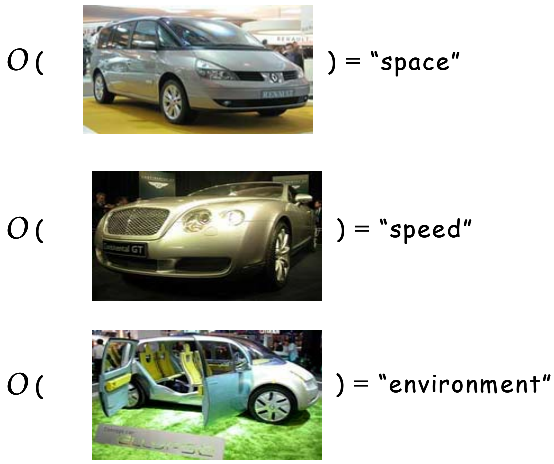

Fig 2: Meaning function about car forms and what they are optimized for.

Similar examples can be given for other aspects of cars, considering syntactically color and material and other aspects of the semantics such as emotions, associations, price expectations, and buyer profiles. Color, form and material were the main constituents of the s-codes that Industrial Designers worked on in the past (next to implementing functionalities, essentially through engineering). In our view behavior must be added as a constituent of present and future product's syntactic s-codes. It has become urgent because of the explosive advancement of computers, software, and telecommunication technologies. Computers and software have the following impact:

- Computers are capable of generating behaviors with a complexity far beyond what was possible with mechanic or electronic means. The behaviors can be designed, exploiting sensor data and based on the results of software and AI research on data filtering, learning, planning and adaptivity.
- Product behavior relates to user action: one invites the other and one responds to the other. Behavior is dialogical, color and material are not; form sometimes has a bit of this two-way interaction. Thus the study of the meaning of behavior essentially is the study of interaction.
- In-as-far as there is already designed behavior, it mostly reaches the user in ways heavily biased by available technologies, not user needs. Often the "dialogue" is unbalanced: information overload via a screen and a clumsy user-to-system device such as a mouse. Remote controls for TVs, DVDs, etc. are designed for being cheap, but are hard to understand, clumsy and not based on natural interaction principles.

Whereas the semantic fields related to aesthetics have been studied for the s-codes constructed from color, form and material, beauty of interaction is still an open field.

2.3 Natural feed-forward and natural feedback

In this section we illustrate the concepts of natural feed-forward and natural feedback. The first is also known as "affordance": the color, form and material of a product tell how the product must be used. The example of Fig. 3 is explained in [3], from we quote: *"The play slider is situated to the right of the tape compartment. The wave-like shape indicates that the play slider can mate with the central part of the tape compartment. By pushing the play slider inwards, the play function is activated. The play slider houses the video-out socket. This is to emphasize that by sliding the play control inwards, information will flow out of the video-socket to the television. Pushing the record slider inwards activates the record stand-by mode [ ]".* The meaning function *I* in Fig. 3 shows the "Invitation" expressed by two specific forms.

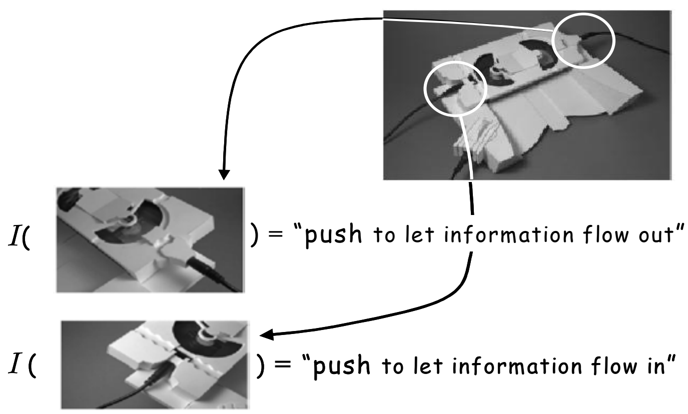

Fig 3: Details of VCR concept where form means invitations for action.

The second is known as "natural feedback". Often it is un-natural to let a product react to a user's action through a modality that is not the same as the modality of the action. If a user pushes a wrong button he finds himself informed by sound or an in-screen notification. This is convenient for the product designers and probably cheap, because the speaker or the screen is there anyhow. But this is a technological reason, not one based on human needs, let alone respect for the human. The following quote, taken from an advertisement illustrates natural feedback: "*To row a WaterRower is to experience a rarity. The smooth feel of water resistance and the responsive mass of the water flywheel are life-like and non-mechanical [ ]. With every stroke, you create the sound of rushing water and each stroke brings a different response."* We shall come back to natural feed-forward and natural feedback in Section 3.2.

3. Interaction

In Section 3.1 we discuss the philosophical and perception-theoretical underpinnings of action as a source for meaning in interaction. Becoming more formal in Section 3.2 a dialogue model is proposed that combines the formality of Eco's semantic approach with an interaction-model coming from computing science. In Section 3.3 some consequences of the model are discussed.

3.1 Philosophical aspects

Designers recently turned to philosophy and perception theory to underpin their approach to action as a source for meaning in interaction. The European phenomenological school contends that meaning is in the world and emerges when interacting with the world. Being (ontology) finds its justification in situated action (Dasein/ being-in-the-world) and no longer in thinking (Descartes: je pense donc je suis/ I think therefore I am). Embodied action is a keyword in this approach, the focus on experience and tangibility a natural consequence [4,5]. Paul Dourish [6] makes an in depth analysis of this approach and its consequences for design. In perception psychology, Gibson coined the term affordance [7]. Building on Gestalt psychology [8], pragmatism [9] and phenomenology [10] Gibson defines affordance as a property of the environment that elicits an organism to behave on the scale of that organism's action possibilities. I am equipped to walk so I perceive my environment as 'walkable' or 'unwalkable', and even 'barely walkable', or 'comfortably walkable'. So perception and action are intrinsically linked, through action possibilities (coined effectivities), through embodiment. Why did designers turn to these people? Design is about materializing meaning. Designers have to shape objects in such a way that they enable people to do things with them. They work the other way round: they create the environment that should appeal to my action possibilities. At the same time, the cognitive psychology approach, underlying classical product design semantics came to a dead end, especially when applied to HCI [11]. So design theory naturally turned to the 'meaning through action' approach.

3.2 Meaning and interaction formalized

To fit interaction, with its dialogical nature, into the semantic framework, we must ask a number of questions: which are the product elements to be taken as signifiers? What are their semantic domains, in other words, about what are these signifiers sending messages? What are the dynamic effects, in other words, in which phase of an interaction do signifiers become available? To address these questions we propose the dialogue model of Figure 4. The dialogue is in the form of a Message Sequence Chart (MSC), which is a standardised notation from Computer Science, used in Telecommunication industry.

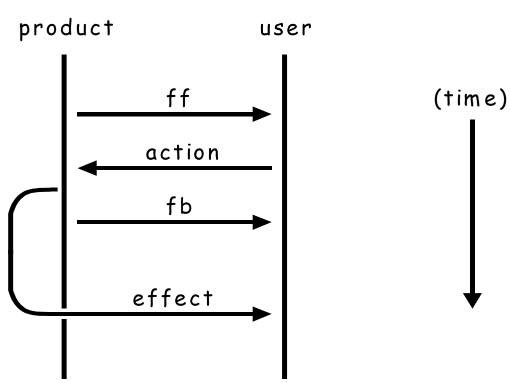

Fig. 4: Message sequence chart model of a dialogue.

The feed-forward message *ff* includes everything classical static semantics can do and also information about the user's options for action (affordance). There may be sequential or parallel messages, but to get started we focus on the simplest case. The user does an *action*, which has a certain effect, although part of this effect remains un-observable (like internal state changes in a computerised system). The user receives a feedback message (*fb*), or a complex of feedbacks. Sooner or later the user will find out the other relevant effects of the action, modelled as a message denoted *effect*.

Now we can answer the first question: which are the product elements to be taken as signifiers? They are *ff*, *fb* and *effect*. And the second question: about what are these signifiers sending messages? This includes everything that can be signified in a classical static semantics, and one extra thing: *ff* must inform the user about the set of actions he or she can choose from. Not only must the user know the s-code of the actions, he or she must know the entire code, including the expectations of each action's effect. If the code is not correctly conveyed to the user, or if the user makes a mistake, or just wants to try, or play, *fb* gives feedback on the action. Moreover *fb* is the feed-forward for the next *action* and so on. Even if the interaction is more complex than this deliberately simplified ping-pong model (like when using physical tools, force-feedback systems and other forms of rich interaction), there will always be feed-forwards, feedbacks and the need to convey the action code.

3.2 Consequences

The dialogue model is capable of explaining many difficulties appeared and still exist since the introduction of products that include embedded processors and thus have behaviors far more complex than traditional mechanical products. The model also points a way ahead: natural interaction and respect for man as a whole. The following remarks serve to justify these claims.

- In a user-interface that just uses a display for output and buttons or a mouse for input, most of the product semantics remains invisible until the product is switched on and its programs become operational. This enlarges the gap between pre-buying product understanding and product usage. In the pre-buying phase, only a small part of *ff* is visible, like a feature list on the box together with a single screen-shot. All interaction issues such as the difficulties of menu-based navigation appear only afterwards. This contributes to the situation where vendors compete on feature-lists, even if most of the users do not want the features and suffer from the increased complexity due to excessive featurization [12]. Another example of this gap is a 2D platform game whose introduction is a nice 3D animation. Note the point, which is not that product semantics can be used for lying (according to Eco, this is even the essence of interesting sign-systems), but that an unnecessary artificial gap arises between what people want and what they get.
- In a user-interface with restricted bandwidth for *ff* (e.g. a small display) *ff* cannot carry the load of conveying the set of actions the user can choose from, together with the entire code of actions and effects.
- People are capable of interaction through a variety of modalities, including vision, sound, speech, text, touch, movements, gestures etc. Many present-day products only support interactions that are based on a very restricted subset of man's modalities and that do not exploit their richness (think of the emotional contents of voice messages next to the spoken text, for example). So man adapts to the product, instead of the other way around. If this is because of technological or cost-restrictions (e.g. remote controls), this is acceptable as a temporary phase; as technology advances, it becomes possible to overcome such limitations.
- When more modalities are used, an interaction is considered natural if the same modality is used for input and output. More precisely, if the user's *action* is based on modality *m*, then the interaction is said to be natural if *ff*, *fb* and *effect* are based on *m* too. The term natural refers to the fact that this congruence (same-

ness) of modality is typical for traditional tools like a hammer. The definition can be extended to time, place and direction. We refer to [13] where principles like ``unity of direction” are detailed further.

- The intertwining of *ff*, *fb* and *effect* relates to Heidegger's discussion on *vorhandenes* (knowing only *ff*) and *zuhandenes* (understanding *ff*, action, *fb* and *effect* through doing). *Zuhandenes* means ‘hands on’. Heidegger denies that *vorhandenes* is more fundamental than *zuhandenes*. Man has a way of understanding in which the interaction itself is basic.
- Man does not consist of only cognition, but cognition, emotion, perception and action. So include fun and emotions in interaction design.

4. Interaction and values

Respect-for-man-as-a-whole is an enabler for conveying other values, e.g. company values. This is because all communication takes place at at least two levels: content-level and meta-level (messages about the way of communication). The degree of respect-for-man-as-a-whole (which is more than user-friendliness) is likely to work as a message at the meta-level. In communication between people this appears in the philosophy of Buber [14], whose central concepts are *Ich-Es*, *Ich-Du* experiences (I-It, I-You). The user-product interaction is of *Ich-Es* type. But behind the product is a manufacturer, a vendor, a designer or a service organization using product semantics to convey value messages. Under circumstances, this could resemble an *Ich-Du* experience in some aspects. But conveying value messages towards a user while at the same time not showing respect to that user contains a built-in incongruity. That is why we plead for a humanistic approach where the product’s behaviour is designed to show respect for the user.

5. Approaches and examples

In this section we look to design approaches that, on the basis of the above framework, are promising to generate new tools, new ways of working and new knowledge for designing products.

5.1 Traditional approaches

The following approaches are bound to fail when used in a stand-alone way, but contain interesting and useful ingredients.

- *Re-using the examples, principles and metaphors of traditional design objects and tools:* there are two good ideas behind this. First, traditional design objects and tools often have their feed-forward, action, feedback and effect well-integrated and natural. Norman [15] gives nice examples, like a door-handle that invites to pull rather than push and where indeed the feedback is through the same modality and at the same location as the action. The second idea is that traditional design objects and tools are mostly based on Tangible interaction, which, as pointed out by Djajadiningrat [13] indeed has the promise of making the most of the user’s perceptual motor skills. But the approach falls short of solving tasks in which computers are essential like data manipulation, expert analysis and control of complex technical systems and programming tasks. These are new semantic domains and new interaction types have to be developed (new codes). A short-term problem is also the lack of sufficiently sophisticated input/output devices.
- *User-interface simulation on a computer:* there are two good insights behind this approach. First, that most of a smart object’s behavior is created through software and that this software is where most of the complexity

resides. Second, that it is wise to experiment with user-interfaces before putting them onto the market; representative users can be observed and they can be asked for their opinion. The problem is the correct representation of tangible interaction, which involves subtleties not easily represented in standard hardware

- *Rigorously defined user-centered engineering processes:* the strong points are that existing knowledge is re-used and experimental evaluation takes place. A weakness is that it is not really helpful for adding fun and emotions to user-interfaces.
- *Tinkering with clay, foam and other playful materials:* the advantages of this are threefold. First, it allows users to be involved in an early phase [16]. Second, it leads away from present computer interfaces and helps rediscovering the richness of tangible interaction. Thirdly, it is a way of testing metaphors and icons and creating new symbols. Designers are in charge of creating new sign codes. Since a code is a cultural thing, the designers must co-create the new sign codes together with society. Metaphors are useful stepping-stones in this process, next to icons and symbols. Tinkering games lead to new experiences and designs, which exist in a cultural sense and hence provide fixed points for making new codes work. Creating new codes is a process of sign creation as understood by Eco. The models are not easily linked to computer-based behaviours, however.

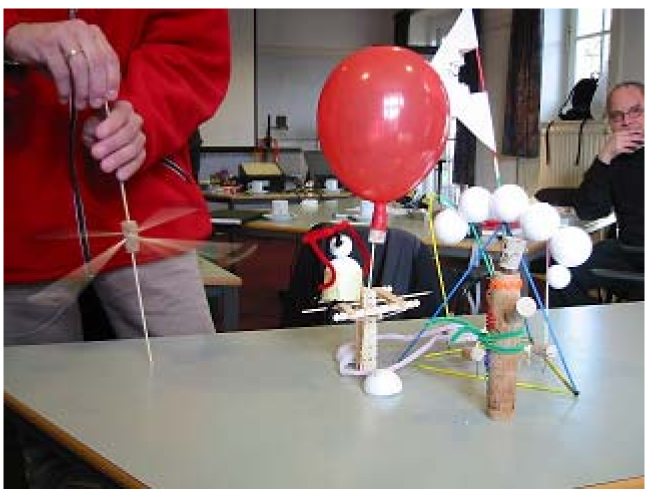

Fig. 5: Tinkering with playful materials to discover new interaction objects.

5.2 New exploration tools for the designer

New research aims at allowing designers to explore interactions. An example is Cubby, described in [17] and further explored in [18]. The display and manipulative spaces are integrated; this technology could be used for exploring new types of interactions by rapid prototyping.

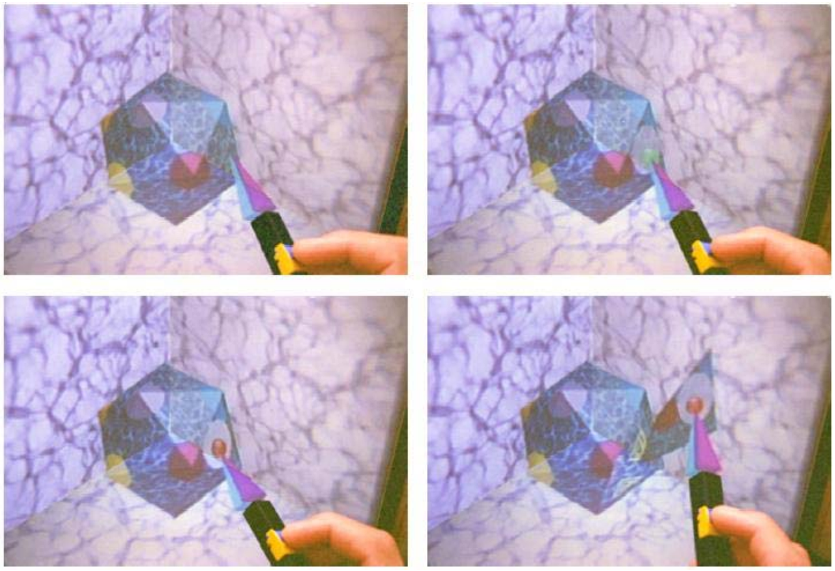

Fig. 6: Cubby, manipulating interactive objects in a VR system.

Another example is described in [19] where physical and digital 3D objects are mixed to prototype healthcare systems.

The Phantom device can be used for developing interactive models; it couples input and output between the computer and user. It is a powerful addition to graphics display for problems that involve understanding of 3D structure, shape perception, and force fields. But supporting tactile feedback ` all its richness is still a problem with most of these approaches.

The research by Hudson (see www-2.cs.cmu.edu/~hudson/) is promising: instead of VR, a library of physical interaction objects is developed. The objects can be combined into working models for exploring interaction. The research creates tools and software to produce high quality user interfaces quickly and economically.

5.3 Adding fun and emotions

Products can read the user's mood from his actions. Wensveen designed an alarm clock that reads a user's mood while he inputs the wake-up time (See Figure 7). The mood is read from the way he interacts with the machine, while feeding it information. A product cannot stay passive in the interaction to allow for all this. First it should elicit actions rich in emotional content through rich action possibilities, through feed-forward. Second, it should tell the user that it understood the time-set and the emotional content of his actions through feedback. A screen shows the wake-up time. A dynamic trace of the action gives inherent feedback, feedback resulting from the actions of the user revealing his mood [20].

Fig. 7: The setting of Wensveen's alarm clock. The expressive setting of the wake-up time is reflected in a dynamic trace of the action.

But a product may not only read emotions, it can also communicate through emotion. Bartneck [21] designed a robot, eMuu, which communicates through emotion (See Fig. 8). By moving his eye brow and mouth eMuu can express how he `feels'. When you negotiate with the robot it reacts to your offers by being sad, happy or even angry. Bartneck found that people have more patience when eMuu makes a mistake as compared to a PC making the same mistake. And they invest more effort in the negotiations with eMuu than with a similar character on a screen.

Fig. 8: eMuu, communication through emotion.

The importance of pleasure and, thus aesthetics, in interacting with products is emphasized in a recently published collection of papers called Funology [22]. In this book Overbeeke makes the case for design as creating contexts for experience, rather than just products. The designer offers the user a context in which he may enjoy a film, a dinner, cleaning, playing, working, *with all his senses*. Bringing together 'contexts for experience' and 'aesthetics of interaction' means that we strive for making the dialogical unlocking of the functionality contribute to the overall experience. Overbeeke believes, on the basis of the philosophical arguments in Section 3.1, that in design the emphasis should shift from a beautiful appearance to beautiful interaction, to engaging interaction. And this should not be a glued on quality. Beauty in interaction is the core, the starting point of interaction design.

6 Conclusions

We presented a theoretic framework for design in which meaning, action and value are integrated. This is done by combining models from formal semantics, perception theory and computer science. Products containing embedded computers will generate behaviors that are far more complex than what was possible with mechanic or electronic means. The framework is helpful to analyze the consequences of this complexity (information overload, more modalities needed, respect for man-as-a-whole). We showed in Sect. 5 how the framework can be used to identify new exploration tools for designers. Also, by examples, we showed that products can use emotions and fun to communicate to users in a meaningful way.

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