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A Conceptually Ambiguous Future for Engineering Design

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Introduction

The analysis of designing may move towards a centre stage position in philosophy when technology is eventually recognised as the discipline aimed at *creating* entities. Technology includes also technical science aimed at *describing* the created entities, but designing may be taken as that what sets technology apart. Separating creation and description more clearly, (natural) science is the discipline by which we describe the entities that we have not created, technical science is the discipline by which we describe the entities that we have created, and technology is the discipline by which we create entities. Creation and description are obviously entangled – in technical designing we use scientific and technical-scientific theories, and in scientific observation we use technologically created instruments – yet designing and production become endeavours that should be discerned from observation and theory development. And where scientific observation and theory development have had their fair shares of attention in methodology and philosophy, technical designing and also production can now be recognised as in need of similar attention.

Considering designing from this broad perspective, one would expect that the analysis of designing will eventually develop towards general and integrative accounts. As scientific descriptions have developed from descriptions of individual phenomena by means of particular concepts into overarching theories phrased in terms of generally shared concepts, characterisations of particular design efforts would evolve into overall accounts of designing phrased in terms of shared concepts. This development can be detected. Design thinking is now seen as a particular way of thinking and attempts to capture it have lead to a number of recent monographs.[1] Yet, one can also observe that the analysis of designing resists this development towards generalisation and integration. There are different methodologies for designing available, and efforts to integrate them are to my knowledge not taken up. Moreover, an alleged precondition to such efforts, being a common conceptual framework for describing these different design methodologies, is not yet satisfied. Rather one can find indications that meeting this precondition is something that researcher in technology reject. Concepts such as technical function and technical behaviour seem central to technology, yet have different meanings for different design methodologists.[2] Moreover, there is no consensus that at some point in the future these meanings can be replaced by single precise ones; hopes towards convergence of the different meanings of function are expressed in, e.g., Chandrasekaran 2005 and Erden *et al*. 2008, but not generally supported. Hence, where in science key concepts such as length, time and mass, have

[1] E.g., Cross 2006, Dong 2009 and Lawson and Dorst 2009.
[2] For the concept of function this is illustrated in, e.g., Chandrasekaran 2005 and Erden *et al*. 2008.

acquired clear, general and unambiguous meanings as given by the *Système International d'Unités*, the key concepts of technology are still ambiguous and specific to particular design methodologies, frustrating attempts to capture designing generally.

There are two ways in which one can understand this ambivalence in design research about the underlying conceptual framework of technology. First one can take it as just a temporary phase that eventually will be surpassed. One then expects that ongoing attempts towards capturing designing will (eventually) be accompanied with analyses of the relevant key concepts aimed at convergence to one generally shared framework. Second one may take it as an indication that such a generally shared conceptual framework is not of value to technology. Science may have had its process of conceptual convergence and may have been helped by this convergence, but for developing technology a generally shared framework may not be needed. One then expects that ongoing attempts towards capturing designing will be accompanied with the introduction of new key concepts, or new meanings for existing concepts, to be used in addition to the existing ones. The second way is philosophically the more interesting one. Technology will then develop differently than science, and mature without creating a generally shared conceptual framework equivalent to the scientific *Système International*.

Topic

The second way of understanding the ambivalence about a generally shared conceptual framework in technology is the topic I want to put on the table. A first set of questions about it is on the chances that researchers in designing and design methodology indeed stick to their current habit of using different conceptual frameworks. In this note I describe some arguments that this habit may persist.

A second set of questions consists of the consequences and conclusions that follow from the possibility that technology end up with multiple conceptual frameworks. My own work on designing has for a large part been focussed on the current lack of consensus among design researchers about how to define technical functions, and has developed towards the position that this lack is present in technology for a good reason. Initially I took the traditional analytic position of philosophy towards disciplines: I identified the different meanings attached to the term function, analysed the problems it led to and suggested that sticking to one meaning would be beneficial to technology. Now I am inclined to turn the tables and accept that engineers use the term with different meanings. The lack of consensus then is part of the phenomenology of technology, and the task for philosophy becomes to understand this lack of consensus: having science as the default, technology is apparently taking a different course in its development, which is therefore in need of analysis and explanation. This is just one illustration of a change in questions when technology adopts multiple conceptual frameworks. What are the other consequences of a conceptually ambiguous future for technology, if such a future is possible at all?

Favouring conceptual ambiguity

That there is currently no consensus in design research about the meaning of key concepts such as function and behaviour is regularly noted by the participants involved. Introductions to special issues of journals consider it (Chakrabarti and Blessing 1996; Chittaro and Kumar 1998; Stone and Chakrabarti 2005) and surveying and discussing the different meanings is a topic in itself (Chakrabarti and Blessing 1996; Chittaro and Kumar 1998; Chandrasekaran

and Josephson 2000; Deng 2002; Chandrasekaran 2005; Erden *et al*. 2008; Van Eck 2009). Hopes that consensus is reached are expressed, as said, (e.g., Chandrasekaran 2005; Erden *et al*. 2008) but a lively discussion about the best way of defining the key concepts is lacking. Typically individual authors propose their definitions, explain how the different key concepts are related within their approaches, and then go on with describing designing. Benefits of adopting the proposed definitions are given but typically not relative to approaches and definitions proposed by other authors. The different conceptual frameworks co-exist peacefully, so to say, and some make the additional step of explicitly accepting that technological key concepts can have different meanings simultaneously.[3]

From this current state of affairs it cannot be deduced that researchers will remain to use different co-existing conceptual frameworks in technology. This fact may, as said, be taken as just a temporary phase in the development of the discipline of technology. Yet, one can argue that the current state of affairs has advantages for engineers, advantages that may keep technology from developing towards a discipline with one general conceptual framework.

Designing with object worlds

A first argument can be derived from the work by Larry Bucciarelli (1994). In his analysis of how engineers design in actual practice, he develops a view in which engineers think and reason by means of conceptual frameworks that are specific to their technical disciplines and possibly even to their personal technical experiences. In Bucciarelli's view engineers work within their specific *object worlds* designating "the domain of thought, action, and artifact within which participants in engineering design [...] move and live when working on any specific aspect, instrumental part, subsystem, or subfunction of the whole." (p. 62) So, engineers in mechanical engineering have their object worlds with mechanical-engineering concepts, engineers in software engineering different object worlds with software-engineering concepts, and so on. Concepts may be shared by engineers with different object worlds but the meanings these engineers attach to those concepts need not be the same. In effect, Bucciarelli analyses in detail a meeting in which engineers are discussing the designing of a residential photovoltaic module, and argues that the way in which decisions are made in designing is determined or possibly even facilitated by the fact that engineers attach different meanings to concepts. For the solar panel the concept of 'module voltage' was chosen as the concept that was to be considered in the meeting by reaching a decision on the value it eventually should have. Bucciarelli then concludes that "[p]articipants capitalize on the variety of its meanings. [...] The umbrella-like, open character of the word provides design participants the room they need to negotiate differing, even divergent, views of the meaning of a network of [photovoltaic] cells." (p. 173) The upshot of this view is that engineers typically use concepts with different meanings and benefit from this when they are designing. Hence, adopting one general conceptual framework for technology would force engineers to give up on this advantage and change the way in which they arrive at design decisions.

[3] In Srinivasan and Chakrabarti 2009, p. 418, the different meanings of function are simultaneously incorporated in the SAPPhIRE model for analytic and synthetic reasoning in designing, and in his presentation at the ICED09 conference Amaresh Chakrabarti described this acceptance of the different meanings as an asset of the model.

Simplifying descriptions of design reasoning

A second argument can be derived from an analysis of why engineers attach different meanings to the key concept of function (Vermaas 2009). This analysis was given as part of the idea that one should accept that engineers attach different meanings to functions, creating the task for philosophy to analyse and explain why engineers do so. The proposal in this analysis is that engineers attaching different meanings to functions in order to simplify descriptions of design reasoning. In a nutshell the analysis proceeds as follows. A detailed description of an artefact is phrased in terms of at least the five key concepts of *goal*, *action*, *function*, *behaviour* and *structure* (Brown and Blessing 2005). The concept of function then has the meaning of 'desired effect of an artefact's behaviour', and designing becomes an activity in which engineers reason in four steps from a (user) *goal* to the physicochemical structure of an artefact. In the first step designing engineers determine a series of *actions* by which users can realise the goal. Some of these actions may involve the artefact that is to be designed and in the second step engineers determine what *functions* the artefact should have, i.e., what effects of the artefact's behaviour are desired in order that the actions are successful. In a third step the *behaviour* of the artefact is determined that can exhibit those intended effects. And in the final step the engineers fix the physicochemical *structure* of the artefact such that the artefact can exercise that behaviour. This description of design reasoning may be adequate but is conceptually far too detailed compared to the descriptions that are given by current design methodologies. In those methodologies some of the five key concepts are ignored and reasoning links goals to the structure of artefacts more straightforwardly. In the design methodology of Gero (1990), for instance, the reasoning proceeds from goals to behaviour, and then from behaviour to structure, and in the methodology of Stone and Wood (2000) engineers reason directly from goals to function, and then from function to structure.[4] Current design methodologies are thus conceptually simpler than the one that follows when one describes artefacts by means of the five key concepts *goal*, *action*, *function*, *behaviour* and *structure*. The current methodologies 'by-pass' references to one or more of these five key concepts, and this by-passing is facilitated by attaching meanings to the concept of function different than the 'desired effect of an artefact's behaviour' meaning. In Gero's methodology function has the meaning of 'design intention or purpose' related to an artefact. With this meaning functions refer to the goals of artefacts in a more explicit way than when functions are 'desired effect of an artefact's behaviour.' By this more explicit reference, design reasoning by Gero's methodology again starts with considering the goals of users. In the methodology by Stone and Wood functions of artefacts are taken or represented as operations on flows of materials, energies and signals, corresponding to the tasks of the artefacts, which attaches the meaning of 'intended behaviour of the artefact' to function. And by this meaning design reasoning with this second methodology still includes considerations of the behaviour of artefacts, considerations that at first sight seem to have been lost. The upshot of this analysis is that engineers use the concept of function with a flexible meaning because that enables them to simplify descriptions of designing. And since there are different ways to simplify those descriptions of designing, as is testified by the co-existence of different design methodologies, they use the concept of function with different meanings.

[4] These reasoning steps are more sophisticatedly described in the methodologies of Gero and of Stone and Wood; the only point I want to make here is that reasoning does not proceed in terms of all five key concepts.

Since the above analysis is meant to explain why engineers attach different meanings to the concept of function, it would be close to begging the question to advance it as an argument that technology will end up with multiple conceptual frameworks. Yet, it shows what is at stake for engineers when giving up on the different meanings. Using these different meanings side by side facilitates the co-existence of different design methodologies. Hence, adopting one general conceptual framework for technology with one canonical meaning of function, would force engineers and design methodologists to rephrase the different design methodologies that employ the concept with other meanings.

A conceptually ambiguous future?

So, can technology evolve into a mature discipline of designing and still employ multiple conceptual frameworks? Can technology in this sense develop differently to science? Will we end up with a clear division where science aims at describing entities by means of one generally shared conceptual framework, and where technology aims at creating entities without needing such a conceptual framework? And how about technical science? Will that end up with a one generally shared conceptual framework?

More specifically: what can we advice design researchers who build computer tools for assisting designing? They would like to have clear and unambiguous definitions of the key concepts used in designing, to have solid ground for developing, say, new CAD/CAM systems and advanced tools for archiving, retrieving and communicating (functional) designs. Should we inform them that they have to realise that such solid ground does not exist? Will databases for functions and functional decompositions always become obsolete when engineers change the meanings they attach to the concept of function?

And which other questions does the possibility of a conceptually ambiguous future of technology raise? Those are the issues I would like to identify with this note.

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