A Critical Analysis of John Gero’s Function-Behaviour-Structure Model of Designing

Pieter E. Vermaas
Delft University of Technology*

Abstract

According to John Gero’s (1990) function-behaviour-structure model of designing, designers transform in three steps desired functions into a design description of an artefact that can perform these functions. Firstly, designers transform the functions into required behaviours of the artefact. Secondly, these required behaviours are transformed into a description of the structure of the artefact. And thirdly, designers transform this description of the structure into the design description that tells how the artefact can be manufactured. In this paper I present and review Gero’s model of designing and show that a precise understanding of this model depends on the precise meanings of the notions function, behaviour and structure. I consider three attempts to characterise functions, behaviours and structure of artefacts and assess how these characterisations affect the model. Also I consider an elaboration of the model by Rosenman and Gero (1998).

1. Introduction

In this paper I give a critical analysis of John Gero’s (1990) function-behaviour-structure model of designing. An attractive aspect of this model is that it breaks up designing in distinct steps, and that it gives a characterisation of the knowledge used in designing. Gero takes designing as a process in which functions are transformed into a design description of an artefact that can perform these functions. A designer makes this transformation according to Gero in three steps. Firstly, he or she transforms the functions into required behaviours of the artefact. Secondly, these required behaviours are transformed into a description of the structure of the artefact. And thirdly, if this description of the structure is satisfactory, the designer transforms it into the design description that tells how the artefact can be manufactured. The knowledge a designer uses to make these transformations is by Gero characterised as knowledge collected by the designer during earlier (alike) design tasks. This design knowledge is brought together in what Gero calls design prototypes. A less attractive aspect is that a precise understanding of Gero’s model depends on the precise meanings of the notions function, behaviour and structure and that Gero initially did not properly lay down these meanings. It is therefore not that clear what Gero initially meant with the distinct steps of his model.

In this paper I present and review Gero’s model of designing. I consider three attempts to characterise functions, behaviours and structure of artefacts and assess how these characterisations affect the model. Also I consider briefly an elaboration of the model by Michael Rosenman and Gero (1998).

I start by sketching Gero’s (1990) model. Then I discuss what Gero initially had in mind when speaking about functions, behaviours and structure of artefacts. Thirdly, I consider two proposals for more precise definitions of functions, behaviours and structure. One is by Robert Cummins (1975), the other by Rosenman and Gero (1998). I argue that these characterisations of functions, behaviours and structure change the understanding of the model considerably: from Gero’s initial characterisation it follows that the knowledge needed to make the different steps of Gero’s model cannot be merely scientific knowledge, whereas Cummins’ definitions and those of Rosenman and Gero seem to allow that scientific knowledge is sufficient for making these steps. Fourthly, I describe Rosenman and Gero’s (1998) elaboration of Gero’s (1990) model. By this elaboration, designing is a process in which human purposes are, via functions and behaviours, transformed into a description of the structure of artefacts that can be employed to achieve the purposes. This elaborated model introduces new steps in designing, namely, transformations between purposes and functions, and decompositions of purposes, functions and behaviours. These new transformations require that design knowledge is again more than just scientific knowledge. I end by analysing the new purposes–functions transformation by means of the description of designing proposed by Houkes, Vermaas, Dorst and De Vries (2002).

2. Gero’s model of designing

In Gero (1990) designing is characterised as a process in which desired functions $F$ are transformed into a design description $D$ of an artefact that can perform these functions. A design description of an artefact consists here of information needed for manufacturing the artefact. Gero analyses this design process and assumes that there do not exist transformations $F \rightarrow D$ that translate functions directly into a design description. He thus rejects the possibility to model designing as a process in which designers directly arrive at design descriptions on the basis of the desired functions. A model $F \rightarrow S \rightarrow D$ according to which designers firstly transform functions $F$ into a description of the structure $S$ of the artefact and then into a design description, is rejected as well; Gero assumes that direct transformations $S \rightarrow D$ exist in general, but that direct transformations $F \rightarrow S$ are not.\footnote{More precisely, Gero assumes that direct transformations $F \rightarrow S$ exist occasionally, but that it is not considered designing if one uses such transformations.} Instead, Gero comes up with a model of designing in which $F$ is transformed indirectly to $S$. This indirect transformation makes use of a detour via the behaviours $B$ of artefacts. Spelled out, Gero’s model is as follows. Firstly, designers transform the functions $F$ into required behaviours $B_r$ of the artefact.\footnote{Gero (1990) uses a different terminology and notation. The actual behaviour of an artefact with structure $S$ is denote by $B_s$ and the required behaviour is called the expected behaviour and is denoted by $B_e$. The present terminology and notation conforms to the terminology used in Rosenman and Gero (1998).} This step $F \rightarrow B_r$ is called formulation. Secondly, designers transform these required behaviours into a candidate structure $S$ of the artefact. This step $B_r \rightarrow S$ is called synthesis. Thirdly, it is checked what behaviours $B_a$ this candidate structure actually exhibits. This step $S \rightarrow B_a$ is called analysis. Fourthly, designers compare these actual behaviours with the required behaviours, $B_a \leftrightarrow B_r$, which is called evaluation. Finally, if the comparison is satisfactory, the candidate structure is transformed into a design description of how the artefact can be manufactured. This final step $S \rightarrow D$ is called production of design description. Given that the evaluation step $B_a \leftrightarrow B_r$ yields a satisfactory result, Gero’s model can thus be taken as consisting of the following sequence of transformations:

\[ F \rightarrow B_r, B_r \rightarrow S, S \rightarrow B_a, B_a \leftrightarrow B_r, S \rightarrow D \]
The evaluation step $B_s \rightarrow B_r$ may also result in the rejection of the candidate structure $S$. This amount to iteration: after the evaluation the process restarts with a new synthesis step $B_r \rightarrow S'$ yielding a new candidate structure $S'$, or continues with a reformulation step $B_a \rightarrow B_r'$ and/or new functions $F'$. In the first case, designing continues with the step $S' \rightarrow B_a$. In the second case, designing may start all over again with the step $F' \rightarrow B_r'$.

Gero’s model simplifies designing by suggesting that designers transpose directly a desired function $F$ into a behaviour $B_r$, and then into one chunk of matter with structure $S$. A more reasonable description is that the desired function is firstly decomposed into a set of subfunctions and that these are transformed into a set of required behaviours. These behaviours may then be decomposed themselves into a set of subbehaviours, and these subbehaviours are transformed into components of an artefact with specific structures. These decomposition steps are part of Rosenman and Gero’s (1998) elaboration of Gero’s model of designing, which is presented in the second half of this paper.

3. Design knowledge according to Gero

How do designers manage to make the different transformations and derive from desired functions, the behaviours, the structure and the design description of an artefact? Gero’s (1990) general answer to this question is that designers proceed by employing what Gero calls design prototypes. A design prototype associated with a particular design process, brings together all the requisite knowledge appropriate to that particular process. It schematises knowledge from alike design cases about the functions, behaviours and structure of artefacts (relevant to the design process) and their relations in terms of, for instance, the dependencies between variables of functions, behaviours and structure. The design prototypes available to a designer originate from his or her own experiences with earlier design tasks. But despite this personal nature of prototypes, Gero suggests that ‘like-minded’ designers will tend to agree on their general content.

Designing using these prototypes goes then as follows: A designer begins with the functions desired by a client. These functional requirements (plus other behavioural or structural requirements the client may have) are used to retrieve potentially useful design prototypes, that is, prototypes that schematise knowledge about designs that have those functions (and satisfy those possible other requirements). These prototypes represent what the designer remembers when he or she examines the client’s requirements. In this way the designer acquires information about the directions the design process can lead to. It facilitates the formulation step $F \rightarrow B_r$ by providing behaviours consistent with the desired functions. And it introduces candidate structure of the artefact needed for making the synthesis step $B_r \rightarrow S$.

Also it helps guiding the analysis step $S \rightarrow B_a$ because prototypes indexed by a given structure $S$ indicate the more regular behaviours $B_a$ that structure is used for in designing. The reformulation step $B_a \rightarrow B_r'$ and/or $F'$ is supported by prototypes because prototypes indexed by a given behaviour $B_r'$ yield information about possible alternative functions $F'$ linked to this behaviour $B_r'$. That is, prototypes at least enable the transformation $B_r' \rightarrow F'$ part of reformulation.

Gero’s claim that designers use knowledge in the design process they have collected during earlier design tasks, is primarily a claim about how designers acquire their knowledge.
It implies that they acquire design knowledge only by designing, or, less strictly, by designing and by taking in knowledge other designers have acquired while designing. Gero’s claim is liberal about the types of knowledge that can become design knowledge: any bit of knowledge that can play a role in a design task can become design knowledge. The claim thus does not impose some kind of constraint or upper bound on design knowledge. On the other hand, design knowledge should enable designers to make the different steps discerned by the model. It should therefore minimally consist of knowledge that enables the designer to transform function into behaviours, behaviours into structure, and vice versa. Design knowledge may, for instance, consist of experiential trail-and-error knowledge collected by craftsmen. In our modern times design knowledge consists of all types of knowledge, ranging from design skills to pure scientific knowledge, and from technological knowledge about operational principles, fabrications techniques and norms, to commercial knowledge.

In the remainder of this paper I now consider the following rather academic question: Can design knowledge, taken as that knowledge that enables designers to transform functions into structure of artefacts, in principle consist of solely scientific knowledge? It is not my intention to argue that designers indeed do or can design on the basis of only scientific knowledge, nor to argue that Gero assumes that this is the case. I merely use this question as a tool to analyse Gero’s model of designing. As I have said, a precise understanding of Gero’s model depends on the precise meanings of the notions function, behaviour and structure. Let’s therefore consider attempts to characterise these notions.

4. Gero’s original characterisation of functions, behaviours and structure

Gero (1990) does not give explicit definitions of what he means with the notions function, behaviour and structure of artefacts; he limits himself to giving examples of functions, behaviours and structure of a window. Functions of a window are the provision of daylight, the control of ventilation, and the provision of view. Behaviour is light transmission, ventilation restriction and view transmission. And the structure of a window consists of the dimensions of the glazing and the frame. Most of these examples suggest that function, behaviour and structure are all physical concepts. Some examples, however, counter this suggestion. The function ‘provision of view’ and the behaviour ‘transmission of view’ seem to introduce concepts that fall partly outside the domain of the natural sciences and to refer to more human related or intentional concepts as well.

In Gero and Rosenman (1990) more examples of functions, behaviours and structure of artefacts are given, and these confirm this latter conclusion. Gero and Rosenman write that functions of artefacts may refer to the goals associated with artefacts. The goal of a shelter may, for instance, be that it is portable. Examples of behaviours are ‘that the portable shelter can be erected within a specific time span’ and the ‘security’ and ‘costs’ of a door. ‘Goals’, ‘times to erect a shelter’, and ‘costs’ are clearly concepts that fall outside the domain of the natural sciences.

By these characterisations of functions, behaviours and structure, it is plausible that scientific knowledge is not sufficient for designing. In order to make, for instance, the formulation step $F \rightarrow B_r$, designers sometimes have to be able to transform the goal ‘portability’ of a shelter into a required maximum time to erect that shelter. And since these features of artefact are not fully physical concepts, science cannot provide for the knowledge

---

3 Gero (1990) gives a list of types of knowledge design knowledge consists of, and it seems evident that this list contains more than scientific knowledge.

4 Gero and Rosenman (1990) examples of the structure of artefacts all fall within the domain of science.
sufficient for making this transformation. Hence, designers need to draw from other sources of knowledge as well.

5. A characterisation of functions, behaviour and structure by means of Cummins

If one tries to be more precise about what is meant by functions, behaviours and structure of artefacts, structure probably does not yield too much difficulty: the structure of an artefact refers to the materials it consists of including the topology and the geometry of these materials. The definition of function and behaviour is, on the other hand, more problematic. For defining functions one may take ones recourses to philosophy because there much work has been done on the conceptual analysis of functions. One, for instance, could turn to Robert Cummins’ (1975) theory of functions. If one does so, the understanding of Gero’s model changes considerably.

In Cummins’ (1975) theory the functions of a system — e.g., biological organs, human behaviour, artefacts — are those capacities of the system that figure in an explanation of a capacity of a larger, containing system. For instance, the propellers on a plane have the function to provide thrust because they have the capacity to provide thrust and because the plane’s capacity to fly is in part explained by this capacity of the propellers to provide thrust. And the heart has the function to pump because it can pump and this capacity explains the capacity of the circulatory system to transport oxygen, waste, etc., through the body. Capacities of material systems are on their turn taken by Cummins as the physical dispositions of those systems. Physical dispositions are properties of systems that manifest themselves conditional on specific antecedent occurrences: when a system has the disposition breakable, it falls to pieces conditional on that it hits a hard object; a propeller has the capacity to provide thrust if it is rotating and provided with fuel. If now the behaviours of an artefact are identified with these physical capacities or dispositions of an artefact, one obtains a clear set of definitions. The structure of an artefact refers to the materials the artefact consists of, and to the topology and the geometry of these materials. The behaviours of an artefact refer to the ways in which the artefact reacts physically to physical occurrences. And the functions of the artefact refer to those behaviours that figure in explanations of behaviours of larger systems that contain the artefact.

A consequence of this set of definitions is that Gero’s model simplifies considerably. For instance, the formulation step \( F \rightarrow B_r \) becomes trivial: the desired functions \( F \) become identical to the required behaviours \( B_r \): both refer to the same dispositions of the artefact to be designed. (Cummins’ definition of function requires that this disposition figures in an explanation of a disposition of a larger system that contains the artefact. At the end of this paper I describe how this disposition and larger system can be chosen.) A second consequence is that scientific knowledge seems almost sufficient to making the other steps in Gero’s model. Both behaviour and structure are now physical notions. Hence, the analysis step \( S \rightarrow B_a \) can in principle be made by deduction from scientific laws, and synthesis \( B_r \rightarrow S \) can in principle be made by abduction from these laws. Evaluation \( B_e \leftrightarrow B_a \) is simply a logical comparison. The only role non-scientific knowledge still can play is to provide for the means to cleverly choose the laws used in the analysis and synthesis steps, and for the transformation \( B_r \rightarrow B_r’ \) in the reformulation step \( B_a \rightarrow B_r’ \& F’ \) (the \( B_r’ \rightarrow F’ \) part of reformulation is again trivial).

An obvious response to this conclusion is that one thus clearly should not adopt this set of definitions if one wants to properly understand Gero’s model of designing. However, as

---

5 I here assume that science provides with ample laws.
I show next, Gero himself seems to accept in Rosenman and Gero (1998) definitions that come close to Cummins’.

6. Rosenman and Gero’s characterisation of functions, behaviour and structure

In Rosenman and Gero (1998) Gero’s model of designing is revisited, and now definitions of functions, behaviours and structure of artefacts are given. In the definition of structure, a difference is made between homogeneous and complex artefacts: the structure of an artefact that consists of one homogeneous element is the artefact’s material arrangement; the structure of an artefact that consists of a complex of homogeneous elements includes the identification of the elements of the artefact, the material arrangement of these elements and their connectivity. The behaviours of an artefact are defined as the artefact’s actions or processes in response to given circumstances of the physical environment. And the functions of an artefact are the results of those actions or processes of the artefact in response to the physical circumstances (i.e., the results of the artefact’s behaviours).

By these definitions, functions, behaviours and structure all are physical concepts. The structure of the artefact refers to the physical make up of the artefact including its topology and geometry. The artefact exhibits by its structure certain physical responses to circumstance in its physical environment, and these are the behaviours of the artefact. These physical behaviours effect certain results, and these are the functions of the artefact.

When Rosenman and Gero’s definitions are compared to those developed on the basis of Cummins, one can conclude that the definitions of behaviours and structure are basically the same, and that those of functions differ on two points. Firstly, Rosenman and Gero take a function as the result of a behaviour, whereas in Cummins a function refers to the behaviour as a whole. Secondly, Cummins is much more selective than Rosenman and Gero: by Rosenman and Gero all possible behaviours of an artefact yield functions of those artefacts (artefacts thus have many functions in addition to those for which they were designed), whereas by Cummins only those behaviours that figure in explanations are functions.

The consequences of Rosenman and Gero’s definitions for Gero’s model are now the following. The formulation step \( F \rightarrow B_r \) becomes an abduction step in which one determines a physical behaviour \( B_r \) on the basis of the result \( F \) of this behaviour. The synthesis step \( B_r \rightarrow S \) also becomes an abduction step in which one determines the physical structure of an artefact on the basis of its physical behaviour. The analysis step \( S \rightarrow B_a \) becomes a deduction step in which the physical behaviours of a given structure are derived. It thus again looks as if scientific knowledge is almost sufficient to making all the steps part of designing.

This latter conclusion may be challenged because Rosenman and Gero (1998) not only have given precise definitions of function, behaviour and structure but also elaborated Gero’s (1990) model. By this elaboration, which I introduce next, new steps have been introduced that cannot be made by scientific knowledge only.

7. Rosenman and Gero’s elaborated purpose-function-behaviour-structure model

---

6 Rosenman and Gero (1998) sometimes discern ‘socio-cultural’ aspects of functions, behaviours and structure. These aspects refer to the interests of designers to pay attention to some functions, behaviours and structural features of the artefacts, and to ignore others. For instance, designers pay attention to only those functions of artefacts that are considered to be relevant for its prospective use. And they describe only those features of the structure of an artefact that enables its manufacturing and the derivation of its relevant actual behaviours. The existence of these ‘socio-cultural’ aspects of the descriptions of functions, behaviours and structure do, however, not force one to take function, behaviour and structure as ‘socio-cultural’ concepts themselves.
By Gero and Rosenman’s (1990) original examples functions of artefacts were allowed to include goals assigned to the artefact. In their (1998) paper they separated functions and goals by identifying the *purposes* of an artefact as distinct to its functions. The general outlook on designing is that humans exist in a natural physical environment and operate in a socio-cultural environment. This latter environment prescribes values and goals and establishes together with the former environment needs of humans. In order to satisfies these needs humans create intentionally artefacts. Rosenman and Gero (1998) now define the purposes of an artefact as the answers to the question of why the artefact does what it does, or what it is for. That is, the purposes of an artefact are the needs of humans that can be achieved with it. By this outlook designing becomes a process that transforms purposes into a design description of artefacts with which those purposes can be achieved.

Rosenman and Gero’s elaborated model of design is now Gero’s original model modified in the following way: Firstly, in order to incorporate purposes, they introduce two new steps. The first step is one in which required purposes are transformed into required functions. This step $P_r \rightarrow F_r$ together with the original formulation step $F_r \rightarrow B_r$, is called *problem formulation*. The second step is one in which the actual functions are interpreted for purposes. This step $F_a \rightarrow P_a$ is called *realisation of utility*. Secondly, Rosenman and Gero make a more systematic distinction between what is required and what is actual; they not only differentiate between required and actual behaviours, but also between required and actual functions and between required and actual purposes.\(^7\) Thirdly, they consider explicitly the decomposition of purposes, functions and behaviours into subpurposes, subfunctions and subbehaviours, respectively. Fourthly, Rosenman and Gero seem to drop the distinction between a description of the structure of an artefact and a design description that tells how the artefact can be manufactured. Fifthly, the analysis and evaluation steps are made more general. Analysis now consists of the transformation $S \rightarrow B_a \rightarrow F_a$. And evaluation consists of a comparison of the actual and required behaviours, functions and purposes.

The extended model for designing can be captured by the following sequence (I have omitted steps which represent the decomposition of purposes, functions and behaviours):

$$P_r \rightarrow F_r, F_r \rightarrow B_r, B_r \rightarrow S, S \rightarrow B_a \rightarrow F_a, F_a \rightarrow P_a, \{B_a,F_a,P_a\} \leftrightarrow \{B_r,F_r,P_r\}$$

*Figure 2:* Rosenman and Gero’s elaborated model of designing

The evaluation steps can lead to acceptance of $S$ as the structure of the artefact or to reiteration via a new synthesis step $B_a \rightarrow S'$ or via reformulation $B_a \rightarrow B_r$ & $F_r$.

Rosenman and Gero again speak about design prototypes that capture the knowledge that enable designers to make these steps. They seem to hold that these prototypes include knowledge about the decomposition of functions and behaviours. But they seem not to expand prototypes in such a way that they also include knowledge about the two new steps $P_r \rightarrow F_r$ and $F_a \rightarrow P_a$. Hence, the way in which designers make these purpose-functions steps is left mysterious; Rosenman and Gero (1998) only characterise these two new steps as teleological reasoning (for a philosopher, intentional reasoning would the term) whereas all other steps are characterised as physical or causal reasoning.

Let’s again return to the question of whether scientific knowledge suffices to design. Function, behaviour and structure are physical concepts by Rosenman and Gero’s (1998) definitions. Hence, the steps $F_r \rightarrow B_r, B_r \rightarrow S$ and $S \rightarrow B_a \rightarrow F_a$ can in principle be made on the basis of scientific knowledge. But purpose is an intentional concept. The new transformations $P_r \rightarrow F_r$ and $F_a \rightarrow P_a$ thus fall partly outside the domain of science, yielding the conclusion that

\(^7\) Rosenman and Gero (1998) sometimes speak about required purposes but usually just call them purposes *simpliciter*. Their term of actual purpose is ‘utility’. 
designers, when designing, need to draw also from other knowledge sources. The same conclusion holds for the decomposition of purposes into subpurposes. The decompositions of functions and behaviours, on the other hand, fall again in the domain of the natural sciences, and can therefore in principle be made on the basis of scientific knowledge. Hence, by the inclusion of the concept purpose Rosenman and Gero’s (1998) model again rules out that design knowledge can consist of scientific knowledge only.

8. From purposes to functions: plans

The problem formulation step $P_r \rightarrow F_r$ in Rosenman and Gero’s (1998) elaborated model may be analysed by means of the description of the design process as developed by Houkes et al. (2002). In this latter description it is assumed that the design process is primarily a process in which plans are developed which users can carry out to achieve specific purposes. These plans consist of series of considered actions where some of these actions typically involve the employment of artefacts. It is not claimed by Houkes et al. that the design process is concerned mainly with developing plans for users — designers are of course most of the time occupied with designing the artefacts that are used as part of the plan. Instead it is claimed that, conceptually speaking, the development of plans comes first, and the designing of the artefacts part of these plans comes second.

Spelled out in more detail (and tailored to the model of Rosenman and Gero (1998)), designers start with required purposes $P_r$. Then they develop a user plan $U$ that consists of a series of considered actions $\{A_i\}$ for which holds that when they are carried out by users, the required purposes are achieved. This plan $U$ is called a user plan because it is a plan developed for users by designers (although, of course, users can also develop their own user plans). The actions $\{A_i\}$ part of the user plan, are to result in specific state of affairs and may involve the use of artefacts. The functions of an artefact used within an action $A_i$ are now defined as those physical dispositions of the artefact that explain that the action $A_i$ results in its specific state of affairs (here Cummins’ (1975) theory of functions is adopted: the artefact is taken as part of the action $A_i$ and the disposition of this action to result in a specific state of affairs is the disposition that is to be explained by the artefact its functions). To give an example, assume that the required purpose is to have a bottle of milk warm enough to feed a baby with. The plan can then consist of the following three actions: put a bottle of cold milk in a container with warm water, wait a couple of minutes, and take the bottle out. The container of warm water used in the second action has heating up the bottle of milk as one of its disposition, and this disposition explains that this action results in a warm bottle of milk. Hence, the function of the container is to heat up the bottle of milk.

The formulation step $P_r \rightarrow F_r$ can thus be analysed as consisting of a planning step $P_r \rightarrow U = \{A_i\}$ and a function determination step $A_i \rightarrow F_r$. The concepts of purposes, plans and actions are not physical concepts, hence it is clear that these transformations of purposes into user plan and actions into functions cannot be made on the basis of scientific knowledge only. Other knowledge about, for instance, human plans and actions, has to be invoked as well.

9. Conclusions

According to Gero’s (1990) original function-behaviour-structure model designing is a process in which required functions are transformed into design descriptions of artefacts via the behaviours and structure of those artefacts. A first conclusion is that given Gero’s original characterisation of the concepts function, behaviour and structure, scientific knowledge does
not give sufficient means to designers to make these transformations since by that characterisation, functions and behaviours of artefacts are not physical concepts. Secondly, attempts on the basis of Cummins (1975) and by Rosenman and Gero (1998) to make Gero’s model more precise by defining the concepts function, behaviour and structure, yield that these concepts are physical concepts. It follows that scientific knowledge is now in principle almost sufficient for designing. Hence, these attempts changed the understanding of Gero’s model considerably. Thirdly, Rosenman and Gero (1998) have elaborated Gero’s model to a purpose-function-behaviour-structure model in which designing is a process in which required purposes are transformed into design descriptions of artefacts via the functions, behaviours and structure of those artefacts. This elaborated model adds transformations between purposes and functions to Gero’s original model, and it can be argued that science does not give the means to make these transformations since purpose is not a scientific concept. Hence, scientific knowledge is again not sufficient to design, although it still is almost sufficient for transforming functions to structures. Fourthly, the transformation of purposes into functions can be analysed by Houkes et al. (2002).

Acknowledgements

It is a pleasure to thank Kees Dorst, Wybo Houkes, Jeroen de Ridder, and especially Larry Bucciarelli for helpful discussions and comments. Research for this paper was part of the program ‘The Dual Nature of Technical Artefacts’, which is supported by the Netherlands Organisation of Scientific Research (NWO) and research efforts by the Techné group.

References