INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

DEVELOPING PLANS OF USE: AN ALTERNATIVE ANALYSIS OF ENGINEERING DESIGNING

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Abstract

Engineering designing is usually taken as a process in which designers transform required functions into descriptions of artefacts that perform these functions. In this paper we present an alternative analysis of engineering designing that aims at improving this usual view by embedding the transformation of functions into artefacts in a more encompassing process. On our analysis designing starts with goals of users. Designers specify these goals and then develop plans (that is, series of actions) by which users can attain the goals. Typically these plans include the manipulation of artefacts. And typically some of these artefacts do not yet exist, in which case designers also give descriptions of the artefacts concerned.

We arrive at this analysis by applying action theory (a theory that describes the relations between actions, intentions and plans of conscious agents) to the using and designing of artefacts. Then we connect our analysis with topics discussed in the literature on engineering and design methodology, specifically the definition of artefact functions, the interplay between designing and using, the categorisation of designing and engineering, design knowledge and proper and rational use.

Keywords: Descriptive models of designing, action theory, user behaviour, design knowledge, types of designing

1. Introduction

Engineering designing is usually taken as a process in which designers transform required functions into a description of the physics of an artefact that can perform these functions (e.g., [1] and [2]). Users figure in this view as the sources of the required functions and as the agents that use the artefacts for these functions.

In [3] we developed an analysis of the process of engineering designing that aims to improve this usual view. By our analysis designers transform required goals into a description of a plan (that is, a series of considered actions) by which these goals can be attained. Designers also transform required functions into descriptions of artefacts, but these transformations are subordinated to the development of plans. In a nutshell our analysis amounts to the following: designing starts with goals formulated by (or for) users. Designers specify these goals and then develop a series of actions (that is, a plan) by which the users can attain the goals. Typically some of the actions concern the intentional manipulation of natural or technically made objects. And typically some of these objects do not yet exist, in which case the designers also describe the objects concerned (and how they can be manufactured).

A reason for giving this alternative analysis was our dissatisfaction with the characterisation of users by the usual view as agents that deliberate explicitly about functions when they consider artefacts. We take the position that users need not express their wishes to designers in terms of required functions, nor need to identify the functions of artefacts when they use

them. Instead, users express their wishes in terms of goals, and use artefacts for attaining these goals. Our analysis of designing is meant to concur with this position: designing starts with goals provided by users, and ends with artefacts and plans for using these artefacts by which users can attain the goals. A second reason for giving the analysis was our dissatisfaction with the characterisation of designers as agents that, apart from an occasional manual, merely create descriptions of material contraptions that can perform functions. This characterisation is too sparse to describe how users learn how to operate newly designed artefacts. We take the position that users learn this not on the basis of only the physics and functions of artefacts (and that occasional manual), but also by information provided by the designers and communicated to users via, for instance, demonstrations and training. On our analysis we can identify this communicated information as information about use plans.

We arrived at our analysis by applying action theory (a branch of philosophy that describes the relations between actions, intentions and plans of conscious agents, see e.g., [4]) to the using and designing of artefacts. In this paper we present this analysis. We firstly describe using as the carrying out of use plans for artefacts (§2) and secondly give the above-mentioned analysis of designing as the development of those use plans (§3). Then we connect our analysis with topics discussed in the literature on engineering and design methodology, and draw conclusions that follow less easily from the usual view of designing. We show that our analysis leads to a definition of artefact function (§4.1), to a richer description of the interplay between designers and users (§4.2), to a categorisation of different types of designing and engineering (§4.3), to the identification of action-theoretic knowledge as design knowledge (§4.4) and to a distinction between proper and rational use (§4.5).

Our aim is to improve the usual view of designing. However, we are philosophers and our analysis is philosophical rather than methodological. Our prime motivation is to understand some central aspects of the using and designing of artefacts; we do not outline detailed procedures that designers can or should follow when they are designing. Moreover, we focus on only a few parts of the design process. We, for instance, ignore the part in which designers transform functions into descriptions of artefacts. Finally our analysis is meant as a rational reconstruction: it is not a description of the actual (and possibly erratic) beliefs, decisions and actions of designers during the unfolding of the design process; it instead is a description of how the design process can be reconstructed as a sequence of beliefs, decisions and actions of a rational designer.

2. Using: attaining goals

2.1 Use plans

Our starting point is that both designing and using are types of action that can be described in terms of plans, goals and practical reasoning. A plan is an ordering of considered actions that are means for achieving an agent's goal [5]. These orderings may be linear, determining the exact order of the actions, or partial, including multiple options. Practical reasoning is the process by which an agent forms plans, based on goals and beliefs. It is often assumed that every action can be *reconstructed* as being based on practical reasoning, even if there is no sequence of explicit decisions and belief-formations in the agent's mind.[1]

By means of these action-theoretic concepts one can describe the using of an artefact by an agent for attaining a goal as the executing of a *use plan* for that artefact – for simplicity's

[1] This 'inferentialist' view is defended in [6], pp. 113–119.

sake, we consider only one artefact.[2] This plan is aimed at attaining the user's goal and should contain at least one action in which the user deliberately manipulates the artefact. Consider, for instance, the using of a blow-dryer. This use can be described as the carrying out of a plan aimed at the user's goal of drying his or her hair, and consisting of the following actions: get the blow-dryer, connect it to the mains,[3] switch it on, rub your hair and simultaneously move the dryer so that the warm air flows over your hair, switch the dryer off, disconnect it and put it back. The ordering of the actions within this plan is to a large extent linear – the dryer should indeed be disconnected only after that the user's hair is dry – but also illustrates that actions within a use plan may be ordered partially – switching off the dryer after it is disconnected from the mains is okay as well.

People have many such use plans available: plans for the same artefact but aimed at different goals (using the dryer for heating surfaces), plans for different artefacts but aimed at the same goal (drying your hair with a towel) and plans for single artefacts and for many artefacts (building a nice fire using a fireplace, some logs, matches and a few balls of paper, and dry your hair in front of it).

2.2 A rational reconstruction of using

The using of artefacts does not consist of simply and mechanically carrying out use plans. As said, agents have many plans available and a rational decision to carry out one of them should at least be determined by the goals the user has and by an evaluation of the artefacts, circumstances and skills required by the plan. If these factors are included in an action-theoretical analysis of using, one obtains a sequence of seven steps containing one loop back at the end to the beginning of the sequence. We have divided the sequence into four phases: one in which the agent decides on the goal to achieve, one in which the agent chooses the plan as the means for achieving this goal, one in which the agent acts by carrying out the plan, and a final phase in which the agent evaluates the results of his or her actions. Our action-theoretical analysis of using is:

goal

U.1 The user wants to realise some goal *g* and believes it does not obtain.

means

U.2 The user believes that carrying out an appropriate use plan *P* that involves the manipulation of artefact *a*, will realise *g*.

U.3 The user believes that the physical circumstances support carrying out *P*.

U.4 The user believes that he possesses the skills needed for carrying out *P*.

action

U.5 The user carries out *P*.

evaluation

U.6 The user believes that *g* has been brought about or that it has not been brought about, based on the observation of *g′* as the outcome of *P* and a comparison of *g′* with *g*.

U.7 The user believes that *g* has been achieved or not. In the latter case, he may decide to repeat sequence *U*, to reconsider his intended goal *g*, or to select another use plan *P′*.

[2] We consider also only the using of artefacts, although our analysis also applies to the using of natural objects. In terms of the illustration given in this paragraph: you can dry your hair in the sun.
[3] The use plan described is thus also a use plan for the electrical mains.

Or, illustrated with the blow-dryer, John wants his hair, which he believes to be wet, dry (*U.1*). He believes that blow-drying it with a blow-dryer will do the job (*U.2*), that there is electricity available (*U.3*) and that he has the skills needed to manipulate the dryer (*U.4*). Then John starts blow-drying his hair (*U.5*) and finally checks the result (*U.6*) and decides whether he has achieved his goal. If not, he may continue blow-drying, forget about his goal, or get a towel after all (*U.7*).

This analysis is clearly rather long-winded and tedious – everyday descriptions of using, e.g., what John would tell his colleagues if the subject came up, are often short and snappy: John wants to dry his hair, grabs the blow-dryer and points it towards his head before rushing off. However, our analysis is meant as a reconstruction of using that (in retrospect) adds to an everyday description all kinds of beliefs, decisions and actions a rational user should have had, made or done, respectively, in order to satisfy the standards set by practical reasoning.

The analysis shows that using of artefacts can be described as the carrying out of use plans for the artefacts with the aim to attain goals. And it proves that even on detailed and long-winded analyses of using, users need not deliberate about the functions of artefacts. The first conclusion paves the way for considering designing as the development of new use plans. And the second motivates our position that functions are not that important to users.

3. Designing: from goals to use plans

3.1 Designing using

Given our analysis of using, designing may still be taken as a process in which required functions are transformed into descriptions of artefacts. This would, however, complicate the relations between using and designing in two ways. Firstly, the source of the functions that prompt designing should be determined. Do users, in addition to attaining their goals by using objects in a planned way, direct designers by formulating required functions, whatever functions may be? Or do designers consider the goals of users and then formulate the required functions? Both options seem reasonable. But once one accepts the latter, one accepts that designing is a process that starts with goals instead of functions. Secondly, it should be determined how users settle on the goals for which and the plans by means of which newly designed artefacts can be deployed. Do designers provide users merely with information about the physics and functions of the artefacts and do users determine the goals and plans on the basis of this information? Or do designers provide more information? Again, both options may be taken, and the latter broadens the description of the design process.

We have shown that users need not deliberate about functions of artefacts. Moreover, we think that designers are not fully appreciated if their profession is limited to transforming functions to artefacts. Therefore, we have chosen to indeed broaden the characterisation of designing in the ways proposed above. We take it as a process in which goals are transformed into use plans and, typically, into descriptions of artefacts that are manipulated as part of those plans. By doing so the connection to our analysis of using is straightforward: designers support users by constructing novel plans by which users can attain new or existing goals.

3.2 A rational reconstruction of designing

Rational designing does not consist of just developing new use plans. Designers choose to develop plans for goals they think are viable in the sense of efficiently attainable, they choose to develop plans that satisfy prevailing (safety, durability, etc.) requirements, and they describe artefacts they believe can be manufactured at reasonable costs. An action-theoretical

analysis of designing that incorporates a minimum of such factors consists of a sequence of nine steps with a number of loops. For simplicity's sake, we consider the development of a plan that requires only one, non-existing artefact. Again we have divided the sequence into four phases:

goal

D.1 The designer wants to contribute to the users' goal *g*.

D.2 The designer believes that goal *g′* is the closest consistent and viable approximation of *g*.[4]

means

D.3 The designer believes that a considered user who is following an appropriate use plan *P* that involves the manipulation of artefact *a* with physicochemical capacity *c*, will bring about *g′*.[5]

D.4 The designer intends to construct a use plan *P* and to communicate it to considered users.

actions

D.5 The designer intends[6] to contribute to producing artefact *a* by describing *a* as well as the way in which *a* can be manufactured, and acts accordingly.

D.6 The designer checks whether the resulting description of *a* is coherent with *P*, and returns to either step 3 or *4* if this is not the case.

D.7 The designer decides to communicate *P* to the considered users, and acts accordingly.

evaluation

D.8 The designer believes that *g′* can or cannot be brought about by considered users to whom *P* is communicated. This belief is based on observing that some of these users go through a sequence of actions *P′* and bring about *g″*, and on comparing *g″* with *g′*.

D.9 The designer decides that her aim to contribute to bringing about *g′* has been achieved or not. In the latter case, she may decide to repeat the entire sequence *D*, settle on another plan (return to step *3*), redesign the artefact (return to step *5*) or reattempt communication (return to step *7*).

This analysis is again not meant as an alternative to everyday accounts of designing, nor as a recommendation for elaborate self-reflection by designers. Instead, it is another long-winded reconstruction that (in retrospect) adds some of the beliefs, decisions and actions a rational designer should have had, made or done, respectively, in order to satisfy the standards of practical reasoning, as set in philosophical action theory. In doing this, it ignores many aspects of actual designing. No mention is made of the beliefs, decisions and actions involved in the interaction between designers and manufactures of artefacts. It merely touches upon the role of safety regulations and standards in designing. It is silent about designing in teams and about the way in which artefacts are described. We believe that our analysis of designing can

[4] This goal *g′* may be identical to *g*.

[5] This belief is based on beliefs about the appropriateness of the means to the considered user's goal, about the physical circumstances of considered use, and about the skills of the considered user.

[6] In action theory, an intention is usually taken as the result of (practical inference from) a desire and appropriate beliefs. Hence, the intention expressed in *D.5* is the consequence of the 'edited' desire *D.1 + D.2* and the appropriate beliefs *D.3* and *D.4*.

be extended in these directions; in [3] we describe more explicitly how designers arrive at the relevant descriptions of artefacts.

Our analysis of designing still does not refer to the concept of a 'function' of an artefact. However, this concept can be included if a function of an artefact is defined as a physicochemical capacity that the artefact is believed to have and that is believed to contribute to the realisation of the goals of a use plan for the artefact, when that plan is carried out. Step *D.3* can then be formulated as: the designer believes that a user who is following a use plan *P* that involves the manipulation of artefact *a* with a function *c*, will bring about *g'*. And step *D.5* then amounts to the description of an artefact with this function.

By means of this analysis of designing together with the preceding analysis of using we can draw a number of further conclusions, which is our next concern.

4. Results

4.1 A definition of artefact functions

As noted above, our analysis shows that the concept of a function of an artefact need not be invoked in descriptions of using but does emerge in descriptions of designing. In that context, artefact functions can be defined as the physicochemical capacities that the artefact is believed to have and that are believed to contribute to the realisation of the goals of a use plan for the artefact, when that plan is carried out. This definition leaves room for improvement, for instance by requiring that the beliefs mentioned in the definition be based on valid grounds [7]. But even in its present form it avoids a number of pitfalls that plague other definitions presented in the literature on design methodology and function theory. In this literature, one can distinguish two opposite camps. One camp links artefact functions to the goals for which they are designed or used and neglects relations to the physics of the artefacts. Artefact functions are, for instance, taken as the designer's intentions or purposes [8]. The other camp links functions to physical features of artefacts and neglects relations to goals or other intentional features associated with artefacts. Artefact functions are then taken as, for instance, the results of the physical behaviours of the artefact [9] or as the physical capacities of an artefact that explain physical capacities of a larger encompassing system [10]. Both types of definition lead to an unwanted proliferation of functions. For instance, if a designer designs a new sophisticated laser-guided saw for a company and intends that this saw will prove that she is a skilful designer as well as helps the company to conquer a market share, then the 'intended purpose'-definition yields that 'to prove skill' and 'to conquer market share' are functions of the saw. And on the 'result of behaviour'-definition the distinction between (proper) functions and side effects is lost; on that definition saws can have the function of spreading sawdust because this can be the result of their behaviour.

Our definition of artefact functions refers to both the physics of artefacts and the action-theoretical beliefs and plans associated with the artefacts. By doing so we avoid proliferation. Not every result of physical behaviour and not every physical capacity that explains other capacities is on our definition a function of an artefact; a physicochemical capacity is only a function if a designer believes that this capacity causes the use plan for the artefact to lead to its goal. The use plans developed for saws do typically not have spreading sawdust as their goal. Hence, saws do not have the function to spread sawdust. Secondly, not every goal of the designer leads to a new function. By our definition artefact functions are only related to physicochemical capacities that contribute to realising the goals of use plans. Thus, commercial or private goals are not artefact functions because these goals do not correspond

to physicochemical capacities of artefacts and are not the goals of use plans developed for users. Proving skills is thus not a function of technically sophisticated saws.

4.2 The interplay between designing and using: communication of use plans

On our analysis, the connection between using and designing is that designers help users to attain new or existing goals by devising new use plans for users, and, if necessary, by describing the artefacts that are manipulated as part of those plans. This connection sheds some light on the question how users learn about the use of artefacts, and shows that a user needs more than information about the physics and functions of an artefact in order to be able to use it. On our analysis, a designer primarily produces and communicates a use plan. The designer tells users what goals can be attained with the plan and should spell out the different actions making up the plan. The means appropriate for this task are demonstrations, advertisement, training, manuals and other activities in which information on actions is communicated. Just presenting artefacts themselves to users and telling them what functions they have is in general insufficient to convey use plans. Consider, for instance, professional equipment or technological complex systems. Installing explosive detection devices in airports and informing staff what their functions are will not do. Handing over a new nuclear power station to a crew with the message that it is for producing electricity and that the manual tells what it is made of, is also not the proper way to proceed. Instead staff and crew are explicitly trained in how to operate these artefacts.

The general picture of the interplay between designers and users that emerges is that users communicate desired goals to designers, and that designers communicate new use plans to users. Designers also hand over (descriptions of) new artefacts to users, but this is subordinate to the communication of the use plan: new artefacts come in boxes with all kinds of pictures and texts printed on them that communicate how the artefacts are to be used and for what, or they come together with vendors or trainers that explain how to use them.

An exception to this general picture may be common-or-garden user products that by their physical structure directly indicate how and for what they can be used. A button is immediately recognised as something to push on, and a cup with a handle is immediately recognised as something to fill and hold. However, these cases can be analysed as cases in which the communication of (parts of) the use plan is established via generally established signs incorporated in the physics of the artefact. We all have learned at some time that buttons are for pushing, and handles for holding. Hence, designers can add such features as means for passing information about the use plan to users. These features are sometimes called ‘use *cues*’, revealing that they do communicate information to users.

Physical signs on artefacts are powerful means for designers to communicate use plans. But they are also sources of confusion. Users that do not understand the use cues added to artefacts, or understand them incorrectly, can arrive at use plans different to the ones developed by the designer and start using the artefacts accordingly. This alternative use of artefacts can on our analysis be distinguished from innovative and deliberate alternative uses of artefacts. In the first case users aim at understanding the use plans communicated by the designer but fail to do so; in the latter case users deliberately ignore the communicated use plans and devise their own. These cases are also different in terms of the strategies available for designers to anticipate alternative uses. If designers want to avoid alternative use caused by misinterpretation of the intended use plan, designers can improve on the communication of this plan; this makes sense since the user indeed attempts to understand what is communicated. If, instead, designers want to avoid alternative uses by users that deliberately ignore the intended use plan, the strategy seems more to add constraints that physically block

those uses. The words ‘pull’ and ‘push’ on UK doors are examples of the first strategy because they support users in their efforts to open doors in the correct way; the mechanical door closers on those same doors seem examples of the second strategy since they block deliberate attempts to leave doors open that should stay closed.

4.3 Types of designing and engineering

Earlier in this paper, we presupposed that some processes count as design processes, and then set out to explore their action-theoretical structure. Now that we have our analysis we may reverse the order of presupposition and exploration. Let us presupposing that all processes that satisfy the analysis are design processes, and explore which processes count as designing. This gives rise to a fairly liberal view of designing: every process in which a use plan is developed and communicated to other agents is a design process, and any agent conducting such a process is a designer. Hence, one need not describe a new artefact to be designing, although this is regarded as a necessary condition on most other analyses.

Secondly, it seems possible to distinguish different types of designing by the analysis. A process that results in a use plan *and* a new artefact can be defined as *artefact designing* (or designing in a strict sense). And a process that results in *only* a use plan can be taken as *redesigning of use* since the use plan is a new plan for an existing artefact. Moreover, one can make a distinction between professional redesigning and (non-professional) *innovative use* of existing artefacts by taking into account the grounds on the basis of which an agent decides that a new use plan for an existing artefact will bring about some goal (step *D.4*). Professional redesigning can be taken as based on technological knowledge and systematic experience about the existing artefact; innovative use can be taken as based on only everyday knowledge about the manipulation of the artefact. But note that an innovative user is still a designer on our analysis. By taking the communication of the use plan and the type of users to which the plan is communicated into account as well, further refinements can be made. Designing of user products is characterised by the communication of the use plans via advertisement, demonstrations and use cues, whereas designing of professional machinery relies for this communication on training and manuals. And designing of components requires that the use plans be communicated to artefact designers.

Thirdly, on the basis of this typology of designing, one may distinguish types of engineering. Disciplines such as industrial product design, architecture and mechanical engineering seem to involve mainly artefact design. The latter may also be distinguished from the former two by noting that in mechanical engineering users (e.g., people operating professional equipment) are usually explicitly taught to carry out the developed use plans (e.g., how to operate the equipment) whereas in industrial design and architecture users are usually not sent to courses. Our analysis seems less suitable to, for instance, civil designing and software design. Designing in those disciplines may be primarily focused on the description of artefacts that can perform certain functions and to a far lesser extent on the development of the corresponding plans of use. This distinguishes these disciplines from industrial product design, architecture and mechanical engineering – leading to a preliminary typography of engineering disciplines – and also indicates possible limitations of our analysis.

4.4 Improving actual designing: action-theoretical design knowledge

We primarily aim at philosophical understanding of central aspects of designing; our analysis is not meant as a model of how actual design processes are or should be organised. But it may be of some help for improving descriptive and normative models. Our definition of artefact functions, for instance, may give engineers and design methodologists a more precise

understanding of the role of this concept in designing – as long as the two rival definitions of functions mentioned in §4.1 co-exist (they even co-exist within single design methodology traditions; the references to the rival camps, [8] and [9], both develop John Gero's [1] model of designing), our understanding of designing is bound to be limited. Secondly, our analysis may improve the characterisation of the types of knowledge invoked in designing.

We argued that designing starts with goals and then includes the development of use plans and descriptions of artefacts. The reasoning involved in this process may be divided into four phases. Firstly, the designer decomposes the initial goal into a number of subgoals that are more feasible that the initial goal. Secondly, the designer identifies actions that realise those subgoals. Thirdly, if these actions require the manipulation of artefacts, these artefacts are defined in terms of their functions. Fourthly, the designer describes the artefacts that can perform those functions. The fourth phase is what usually is seen as designing, neglecting the first three phases. So we expect that the knowledge needed to conclude this phase is properly analysed elsewhere. But the knowledge required for the first three phases may have been neglected. Our analysis may initiate the analysis of the action-theoretical knowledge about goals and their decompositions, about the relation between actions and goals, and about the relation between the goals of actions and the physical capacities of objects manipulated as part of those actions. Unfortunately, such an analysis, or even a conjecture about its results, is at present outside our reach.

4.5 Proper versus rational use

One advantage of describing use and design in terms of plans is that it becomes possible to impose the various standards of rationality for such plans [4]. Their goals should, for instance, be realisable simultaneously and the planning agent should rely only on beliefs he or she actually holds. Moreover, a rational plan is means-end coherent: the means chosen must be considered appropriate to the goals [6]. This implies that the user should believe that the use plan he selects is appropriate for realising his goal.

These standards can be used to make pre-reflective assessments of use more precise and variegated. Warranties, for instance, often contain a clause to exclude damage caused by 'improper' use of the artefact in question. Our analysis shows that such alternative uses need to be discredited. *Any* use plan that answers to the standards of practical rationality is 'acceptable' in the sense of being rational. Yet only those use plans that are in accordance with the ones designed for the artefacts may be called 'proper'. The distinction between rational and proper use leads to four different assessments of use. Using a blow-dryer to soothe a baby with its monotonous noise, for instance, is means-end coherent, as one of us can testify, and therefore rational. Nonetheless, it is probably not in accordance with the designed use plan for blow-dryers and thus improper – the designer does not guarantee the rationality of the plan, so to say. Conversely, users can only hope that proper use is rational, i.e., that the designed use plan is as effective, safe and durable as the designers think it is. The void clause on warranties, finally, may be taken to apply primarily to use that is both improper *and* irrational – such as using a blow-dryer to dry one's hair while taking a shower.

5. Conclusion

In this paper we have shown that engineering designing can be analysed as a process in which designers transform goals of users into descriptions of use plans for artefacts by which users can attain these goals. Designers often also transform required functions into descriptions of

artefacts, but these transformations are subordinated to the overall process of developing use plans.

By this analysis users of artefacts need not express their wishes to designers in terms of required functions, and need not identify the functions of artefacts when they use them. Instead, users express their wishes in terms of goals, and use artefacts by means of plans for attaining these goals. And designers are not merely agents that create descriptions of material contraptions that can perform functions, but they develop and communicate to users plans by which users can attain their goals. Finally, we used our analysis to present a definition of artefact function, a description of the interplay between designers and users, categorisations of different types of designing and engineering, a call for attention for action-theoretical design knowledge, and a distinction between proper and rational use. Yet we do acknowledge that our analysis is a philosophers' analyses aimed at conceptual clarification. The question whether this analysis is of worth for designing itself, we humbly leave to the experts.

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).

References

[1] Gero J.S., "Design Prototypes: A Knowledge Representation Schema for Design", AI Magazine, Vol. 11, No. 4, 1990, pp.26-36.

[2] Roozenburg N.F.M. and Eekels J., "Product Design: Fundamentals and Methods", John Wiley & Sons, Chichester, 1995.

[3] Houkes W., Vermaas P.E., Dorst K. and de Vries M.J., "Design and Use as Plans: An Action-Theoretical Account", Design Studies, Vol. 23, 2002, pp.303-320.

[4] Bratman M., "Intention, Plans, and Practical Reason", Harvard University Press, Cambridge MA, 1987.

[5] Audi R., "Intention, Cognitive Commitment, and Planning", Synthese, Vol. 86, 1991, pp.361-378.

[6] Audi R., "Practical Reasoning", Routledge, London, 1989, chapter 7.

[7] Houkes W. and Vermaas P.E., "Artefact Functions", 2003, Delft University of Technology manuscript.

[8] Gero J.S., Tham K.W. and Lee H.S., "Behaviour: A Link Between Function and Structure in Design". In Brown D.C., Waldron M.B. and Yoshikawa H. (eds), "Intelligent Computer Aided Design", Elsevier, Amsterdam, 1992, pp.193-225.

[9] Rosenman M.A. and Gero J.S., "Purpose and Function in Design: From the Socio-Cultural to the Techno-Physical", Design Studies, Vol. 19, 1998, pp.161-186.

[10] Cummins, R., "Functional Analysis", The Journal of Philosophy, Vol. 72, 1975, pp.741-765.

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