

GUEST EDITORIAL

My functional description is better!

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1. INTRODUCTION

Functional description is a fertile and versatile issue in engineering design research. It has a long history in traditional mechanical engineering, and it is gaining in importance as industry is adopting system engineering approaches to integrate mechanical engineering with electrical and control engineering as well as with software design. Engineering functional description is, moreover, increasingly becoming a topic in its own right.

Over the past decades and at various universities all over the world, different views of how to create functional descriptions have been developed from two distinct viewpoints: as part of methods and tools developed to support designers and engineers in industry, and as part of artificial intelligence research aimed at supporting and automation of reasoning about product functions. These different views on functional description have been taught in academia in conjunction with the associated methods and tools, educating generations of engineers in functional description. Through these graduate engineers, functional descriptions disseminated to industry. All of these efforts provided functional description with an enduring basis in research and gave function the status of a key concept in engineering and design. However, the phenomenon that *different* views on functional description have been developed also led to problems. Although each view may be internally consistent and be a basis for useful methods and tools, the coexistence of different views created separate academic traditions, where each tradition advances different ways of describing products and their design. The different views on functional description lead to different basic terminologies with subtle or gross differences in the meaning of function and of related key concepts such as behavior and purpose. The coexistence of these different traditions is now hampering further developments and usages of functional description in academia and industry. At conferences, new results and applications of functional descriptions are

presented, creating progress within the separate traditions but limiting opportunities for cross-fertilizations. In the dissemination of results to industry, academia effectively exports its separation in traditions, thus arriving at the less attractive proposition that industry should adopt the different ways of giving functional description and implement methods and tools that are not straightforwardly combinable.

Engineering design researchers operating within the various traditions have by and large ignored the existence of the different ways to give functional descriptions. Research on methods and tools using a particular way of giving such descriptions is flourishing, but an active and general effort at overcoming the differences is absent. Researchers may have the belief that “my functional description is better,” but in the literature such a position is rarely found nor explicitly defended. The phenomenon that functional descriptions can be given in different ways launched other efforts. In engineering design research, the different ways have been analyzed and surveyed (e.g., Erden et al., 2008; Crilly, 2010). In artificial intelligence research, efforts have been made to provide functional description a more explicit basis, for instance, by introducing in applied ontologies a new unambiguous concept of function for engineering and by finding the relations between the existence functional descriptions (e.g., Kitamura et al., 2005). In addition, historical and philosophical analyses of the roots of the differences between the traditions have been presented (e.g., Far & Elamy, 2005; Vermaas, 2009, 2010). These efforts amount to looking for further ways to give functional descriptions in the hope that one of them can become the prevailing paradigm, or to accepting that multiple interpretations are possible. The resulting picture is that the existence of different ways of giving functional description is more or less accepted in engineering design research and that addressing this phenomenon is now a task taken up in a wider variety of disciplines.

This Special Issue on functional description in engineering aims at making this picture explicit and at exploring the ramifications of the current thinking about the coexistence of functional descriptions to engineering design research, to en-

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engineering education, and to the dissemination of functional methods and tools to industry.

2. THE PROBLEM

The existence of different ways of giving functional description is by now creating two problems, each at a different level. First, it confronts engineering with an ambiguity at the very core of design methods and engineering tools. Engineers and designers using these methods and tools have to deal with this ambiguity when they communicate with each other and when they have to combine methods and tools. Engineers and designers have to become aware of the ambiguity and avoid confusion and error. Such communication problems exist in academia, at conference and in research, yet are also hampering the application of the results in industry. The use of functional methods and tools in industry may also lead to confusion, error, and eventually rejection, as long as industry is not aware that function may mean different things for different methods and tools. Second, the problem is that in design research the first problem of the ambiguity is by and large ignored. The different traditions using particular ways of giving functional description are well established and therefore also well entrenched. Researchers become immersed in the basic terminologies part of the traditions they are part of, making it increasingly difficult to further engineering design research by overcoming or accepting the ambiguity of functional description and thus establishing a more well-defined and transparent transfer of functional methods and tools to industry.

Both problems may be addressed by starting a downward “my functional description is better” discussion in engineering design research and aiming at imposing a single shared concept of function to engineering. However, this need not be the only way to advance. One of the results that emerges for this Special Issue is that the different ways of giving functional description may be related to the different engineering tasks taken up with methods and tools using functional description. This would mean that the ambiguity of functional descriptions is not to be rejected but to be accepted. It can then be made explicit that different functional methods and tools are based on different functional descriptions, precisely because they are meant to address different engineering tasks. A “my functional description is better” discussion can then still be started, but now for making explicit that particular functional descriptions are better suited for particular engineering tasks. This second resolution would not make the dissemination of functional methods and tools to industry instantly attractive, yet it may make more transparent why functional descriptions are to be taken as ambiguous.

The ambiguity of a key concept and the possibility that this ambiguity is to be accepted would make function a special key concept in engineering. However, by having such a special concept, engineering would not be set apart from science; in addition, in biology the use of functional descriptions is analyzed as ambiguous and as depending on specific explanatory

tasks (e.g., Wouters, 2003). What currently sets engineering apart is the second problem that design researchers largely ignore that functional descriptions are currently ambiguous.

3. THIS SPECIAL ISSUE

This Special Issue is organized to address specifically the second problem by facilitating among researchers interested in functional modeling a debate about the current ambiguity of functional description. To get engagement of different researchers, the format of position papers and solicited responses was chosen. The Special Issue has three position papers. In the first, Pieter Vermaas discusses how design researchers could respond to the existence of different ways of giving functional descriptions. In the second, Ashok Goel provides a perspective on how his views and those of the ontology community on functional descriptions have developed over the past 30 years and gives 15 principles for functional modeling. In the third position paper, Claudia Eckert discusses the challenges that engineers face, specifically in industry, when using functional methods and tools, showing the impact the diversity of views in academia has on practice. Authors of response papers were invited to build on the three position papers and to take issue with the arguments they put forward. This is a format used quite often in philosophy but only rarely in the engineering design community. A response paper is not a standalone research paper in the conventional sense; it is intended to be read in conjunction with the position papers. For example, the response papers may have less detailed literature reviews, because they draw on the Vermaas position paper for this. In addition, authors of response papers may advance arguments based on assumptions and empirical results, and refer for the necessary support to other work.

This Special Issue does not aim at also finding a definite resolution to the first problem that functional description is ambiguous. Some contributions do advance one particular way of defining function and fit in various degrees the “my functional description is better” approach. Nevertheless, the Special Issue contains a number of such contributions, which disagree on the particular definition that is to be adopted. This Special Issue does, however, more than just bringing together the different ways of giving functional description, as was done in earlier Special Issues in this and other journals (e.g., Chakrabarti & Blessing, 1996; Chittaro & Kumar, 1998; Stone & Chakrabarti, 2005a, 2005b). The aim is to bring research on the topic of functional description further by work that makes explicit the reasons authors may have for adopting specific ways of giving functional description; it is meant as a first step toward a debate in engineering how to best understand and respond to the existence of different ways of giving functional description.

4. THE SOLUTION

One solution to the problems caused by the coexistence of different ways to give functional descriptions may consist

of giving a single concept of function and arguing that it should be the one shared in engineering as the better concept. The contributions by Thomas J. Howard and Mogens Myrup Andreasen and by Yong Chen, Zhinan Zhang, Jian Huang, and Youbai Xie represent this resolution. However, their proposals and the arguments these authors give for their proposals differ. Where Chen et al. draw from a general ontological frame for science as developed by Bunge (1977) for giving a precise and well-analyzed concept of function, Howard and Andreasen support their link model proposal with design knowledge and with their experiences in educating engineers. The position to endorse one concept of function clearly solves the ambiguity of functional descriptions and may be taken as a more daring position because the current situation in engineering is one of acceptance of the different ways of giving functional description. The contribution by Howard and Andreasen to some extent tries to avoid this clear conflict with current engineering practices by actually accepting two concepts of function simultaneously, thus partly reintroducing the problem it aims to resolve.

An alternative solution is to accept different ways of giving functional description and to propose specific concepts of function for specific tasks. Marco Aurisicchio, Rob Bracewell, and Gareth Armstrong advance their functional analysis diagram modeling as a pragmatic approach to describing functions that industry can use for, in particular, incremental engineering design. Aurisicchio et al. still claim that their modeling may also be used for more innovative design projects but requires an architecture on which the functional description is anchored. However, they explicitly acknowledge that other ways of giving functional description might be useful as well.

When the different ways of giving functional descriptions found in current engineering design research are accepted, the follow-up question becomes how these different functional descriptions are to be related to one another. Specifically, Yoshinobu Kitamura and Riichiro Mizoguchi have worked extensively on this question in the context of applied ontologies, and their contribution to this Special Issue brings together their achievements in introducing a rigorous concept of function and in relating this concept to existing ways of functional description in engineering. In the contribution by Amaresh Chakrabarti, V. Srinivasan, B.S.C. Ranjan, and Udo Lindemann a new proposal for a general and overarching concept of function is defined. This overarching concept is presented as having existing engineering concepts of function as instances, and some of these existing concepts are identified as serving specific engineering tasks. Boris Eisenbart, Kilian Gericke, and Luciënne Blessing have identified which of the many ways of giving functional descriptions are used in the different engineering disciplines, conjecture that engineers in design may want to flexibly switch between these different ways, and argue that a minimal shared concept of function may enable these engineers to integrate the various functional descriptions created.

The analyses given in specifically the contributions by Chakrabarti et al. and Eisenbart et al. are in line with the per-

spective presented and explored in the position papers by Vermaas and by Goel that engineers use the different functional descriptions for different tasks part of engineering. This perspective leads in turn to the questions what tasks there are in engineering for which functional descriptions may be useful, and what constraints functional descriptions should meet in order to be actually useful. The final response papers in this Special Issue may be seen in this perspective. Sen and Summers argue for six requirements on functional modeling to be useful for the engineering design task of qualitative and quantitative reasoning and analysis. Finally, Tetsuo Tomiyama, Thom J. van Beek, Andrés Alberto Alvarez Cabrera, Hitoshi Komoto, and Valentina D'Amelio identify problems industry has with applying functional methods and tools, in line with the position paper by Eckert, and propose three strategies for engineering design researchers to make functional descriptions (more) attractive and clear to industry.

5. AN OUTLOOK

The aim of this Special Issue is to further research on the topic of functional description by work that makes explicit the reasons authors may have for adopting specific ways of giving functional description. The contributions to this Special Issue vary in terms of content, where some argue for specific concepts or overarching concepts of function and others reflect on the conditions that have to be satisfied by functional descriptions to be of use to particular engineering tasks. Nevertheless, all contributions aim at reflecting on the positions taken towards functional description and at giving the arguments for advancing these positions. We see this as progress in research on functional description in engineering, and we see it as a development that may bring new research efforts on this issue.

Reflection on the positions taken toward functional description may still lead to an effort toward a single or at least predominant concept of function in engineering, and the reflection may then lead to a more explicit consensus about this single concept. The contributions of this Special Issue also aid the acceptance that function is an ambiguous concept, with a meaning that engineers adjust to the task at hand. Reflection on functional description then leads to novel research questions on the relation between specific functional descriptions and specific tasks for which they can be used.

However, whatever way research on functional description will go, it seems that there is a clear need for a "my functional description is better" approach in research. If research is to aim at a single concept of function in engineering, the arguments why this single concept is to be preferred over others have to be made explicit in order to convince researchers in academia and practitioners in industry. If research is to aim at different concepts of function geared toward different tasks in engineering, the arguments why one particular concept is to be preferred over others for a specific task again have to be made explicit to convince researchers in academia and to inform practitioners in industry. Consensus in academia

about how to give functional descriptions is a prerequisite to teaching graduate engineers in a consistent way and to introducing functional description equally consistent to industry through these future engineers.

Hence, by making the reasons authors may have for adopting specific ways of giving functional descriptions explicit, these descriptions can be compared and engineering design research can also meet the engineering value of efficiency by determining which functional descriptions are best for engineering.

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