Supporting Two Views of Function in Mechanical Designs[1]

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Abstract

The paper argues that function of an object is distinct from its behaviour in that it is intentional rather than actual or expected, and proposes that there are two related but distinct views of function in the present literature. In one view, it is at the same level of abstraction as behaviour (intended behaviour), while in the other it is at a higher level. (purpose). The project reported is an attemprt to support both these views in the context of conceptual design of mechanical systems.

Introduction:Two Views of Function

The goal in design is to develop a solution which satisfies some intention. This entails three major tasks: generation, evaluation and modification of solutions. Generation involves developing solutions that work as intended. Evaluation involves judging whether a solution could satisfy the intention. Comparing intention with what a solution could offer is therefore important in all these activities. However, a central difference between the activities in design and post-design (such as maintenance and repair) is that while in the post design activities the intentions and the structure of a solution are well-understood in detail, it is far from so in design, especially during its early stages. Therefore, in less concrete tasks such as conceptual design, one could only postulate how a potential solution *might* behave rather than how it *actually* behaves. We will call these its *expected* behaviour.

Existing functional reasoning literature views function in two related but distinct ways. One may be described as *intended* behaviour [Pahl & Beitz, 1984; Finger & Rinderle, 1990; Chakrabarti & Bligh, 1994, 1996a, 1996b] and is at the same level of abstraction as the expected behaviour (ie, both use the same state variables for their description and use components only within the system boundary of the solution), and could either be a subset, or an aggregate (of a subset) of the expected behaviour. For instance, an intended behaviour of a door latch is to press a door handle to cause a wedge to retract, which may be achieved by the expected behaviour of a chain of components which together transform the motion of the handle into that of the wedge (Figures 1, 2 and 3).

In the other meaning, function (such as temporarily locking a door against wind) is an interpretation at a higher level of abstraction of the intended behaviour of a solution (eg, movements of the wedge and handle) [Kannapan & Marshek, 1991; Narasimhan et al., 1993]. Therefore, while the intended and expected behaviour reside at the same level of abstraction, function in this latter teleological sense could be viewed at several levels of abstraction, depending on where the system boundary for the context to a solution is drawn. In this sense, a clock's 'why' (to tell time) and 'what' (to indicate marks arranged in a certain way) functions in Rosenman & Gero [1993] both are teleological, requiring more than the clock's mechanism for their determination.

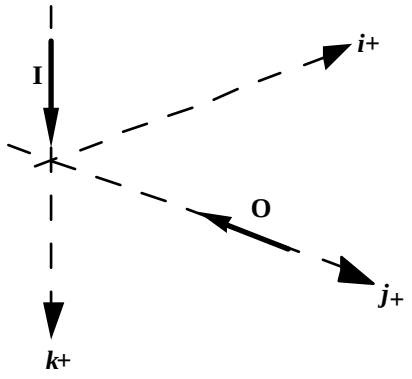

Fig. 1 Intended Behaviour of a Door Latch

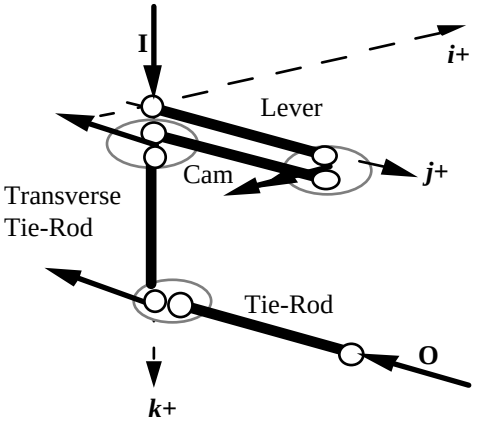

Fig. 2 Expected Behaviour of the Latch

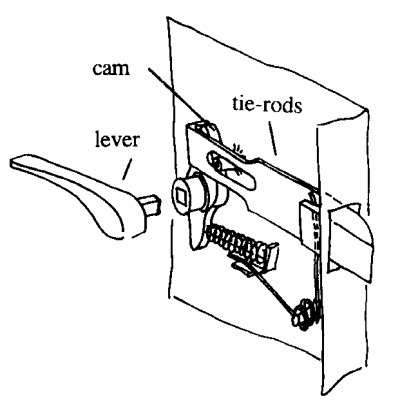

Fig. 3 The Physical Structure of a Door Latch

The distinguishing feature between function and behaviour is often confused as *the level of abstraction* (eg, in Kaindl, 1993, behaviour of a boiler steam valve is taken as opening at some prescribed pressure, and function is taken as prevention of explosion), while it should be the *intentionality* (and therefore, in a design problem, releasing steam at a maximum pressure is one possible intended behaviour for preventing explosion). Both the views are valid in this sense that they both distinguish function as intentional from the existing, available or expected, and both need to be incorporated in any system which intends to support reasoning that seeks to answer questions like these:

1. Could a given potential solution provide a given intended behaviour?
2. Which solutions could provide a given intended behaviour?
3. Could a given solution contribute to a given intended higher level behaviour
4. Which solutions could contribute to a given intended higher level behaviour?

Several attempts to answer questions 1 [Joskowicz, 1989; Gelsey, 1987] and 2 [Hoover & Rinderle, 1989; Ulrich and Seering, 1989; Kota & Chiou, 1992; Chakrabarti & Bligh, 1994, 1996a, 1996b] is cited in literature. Important as it is, however, little research exists into answering questions of the types 3 and 4. Crucial for this is an understanding of the relationship between functionality at various levels.

Relationship Between the Two Views

The relationship between these two views of function is investigated by probing further into the door latch design. Its high level function may be to contribute to the temporary (un)locking of a door, so as to control, at another level, movement of material, information or energy across it. At the behavioural level, a function may be for a wedge to retract when a specific handle is turned. Each of these descriptions inform us about some aspects of the functionality of the device, but are fragmented in that they do not make sense as a whole. Although some projects [Umeda et al., 1996; Bracewell & Sharpe, 1996] attempt to support manipulation of both forms of functionality, they do so by associating specific high-level functions with low-levels functions without modelling how the association emerges, thereby providing tools for documenting rather than assisting in reasoning to develop or evaluate these associations. What we need is to understand the relationship between high and low-level functional descriptions so as to support synthesis of solutions to satisfy functions of the device at these various levels of abstraction, and evaluate a given solution for these functions.

These various levels of functionality are related to one another via models of the solution (latch) and its context (door and frame), not just at various levels of granularity (ie, a black box of inputs and outputs described in terms of a combination of black boxes amounting to having the same overall inputs and outputs), but *described in terms of different parameter-sets*, which are interpreted (or implemented) in terms of each other. For instance, at one level the door latch function is to contribute to changing the degrees of freedom of the door, and at another, as providing spatial overlaps between the door and the frame; at yet another level these may be described in terms of the motion states of the latch. The motion states are interpreted in terms of spatial overlaps, and spatial overlaps in terms of degrees of freedom.

Summary and Research Plan

The main messages of this paper are: (i) function is distinct from behaviour as being intentional rather than actual or expected, (ii) two distinct forms of functions exist, one as intended behaviour and the other as its interpretation at higher levels, (iii) these are related via context within which the design works, (iv) it is important to support reasoning to develop or evaluate such relationships.

The main objective of this project is to support mechanical designers during the conceptual stages of design, especially in formulating the intended functions, in synthesising potential solutions to satisfy them, and in evaluating these [Chakrabarti & Bligh, 1996c]. We wish to give designers an interactive platform where they should be able to describe the context and functionality of a design problem, to develop structural and behavioural aspects of its solutions, and to reason so as to check and ensure that the functionality is achieved at multiple levels of abstraction. However, without an adequate *geometry-based* representation of solutions and their contexts, this cannot be achieved. The major tasks envisaged are: (i) modelling expected behaviour of a solution at several abstraction levels, (ii) modelling intended behaviour of the solution at these levels, and (iii) relating these models, so that the above tasks could be supported.

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