Function propagation through nested systems

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Concepts of function are central to design but statements about a device's functions can be interpreted in different ways. This raises problems for researchers trying to clarify the foundations of design theory and for those developing design support-tools that can represent and reason about function. By showing how functions relate systems to their sub-systems and super-systems, this article illustrates some limitations of existing function terminology and some problems with existing function statements. To address these issues, a system-relative function terminology is introduced. This is used to demonstrate that systems function not only with respect to their most local super-system, but also with respect to their more global super-systems.

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Concepts of function are important for the study and practice of design. For example, it is common to hear statements such as "the function of a motor is to convert electrical energy to rotational energy" or "the function of a corkscrew is to extract corks from bottles". More generally, these statements are of the form "the function of X is Y", by which it is variously meant that X is intended to Y, is used to Y, has been selected to Y, and so on.[1] Such statements are important for developing and analysing the components and products at which they are aimed, whether those objects exist or are only imagined. Function assignments are thus central to design research, to design tool development and to design activities themselves (Winsor & MacCallum, 1994). Despite this key role in design, the word 'function' means different things to different people, and can mean different things to the same person depending on context. So, function is at once intuitive and important, but is also either vague or overloaded (for recent commentaries, see Erden et al., 2008; van der Vegte, Horváth, & Mandorli, 2011; for evidence from design practice, see Eckert, Alink, Ruckpaul, & Albers, 2011).

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Ambiguity surrounding function statements leads to difficulties in formally describing or modelling function. This problem has attracted attention in two distinct areas of design research that both seek a clear ontology for design.

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On the one hand, philosophers of design are concerned by the confusion surrounding function concepts and by the disconnect with other domains of function theory (e.g. Galle, 2009; Houkes & Vermaas, 2010; Kroes, 2010a, 2010b). On the other hand, design methodologists note that inconsistency with function hinders efforts to develop technologies (such as CAD systems) that can represent and reason about the function of a device rather than just its geometry (e.g. Umeda & Tomiyama, 1997: p. 43; also see Chakrabarti et al., 2011). With such challenges and opportunities in mind, my aim here is to explore and clarify what function statements involve. This is with a view to contributing to philosophical work in this area, whilst also recognising that such work may in turn contribute to those areas in which the representation of function has practical consequences for design practice.

Efforts to clarify or elaborate the meaning of function have led function theorists to acknowledge that it describes at least two different concepts. These concepts are commonly referred to as *device-centric functions*, focussing on the internal behaviour of the device, and *environment-centric functions*, focussing on the external effects that a device has on the things around it (Chandrasekaran & Josephson, 2000). The device–environment distinction clearly separates one type of function statement from another, and also indicates how different perspectives on the same device may lead to different functions being assigned to it. What is less clear is how a device's functions should be defined when that device (internally) has components within components and when it (externally) affects environments which in turn affect their own environments. This view of devices actually represents the general case, and so it is important to be able to account for it in our definitions and representations of function. Such matters are at the heart of this article, matters which I seek to clarify by exploring and illustrating the system-relativity of functions.

Considering the relationship between functions, components and environments is not new; it is a long-standing feature of the literature on systematic design methods. This can be seen in descriptions of functional decomposition and system composition. In such processes, designers (i) identify an overall function that the system must perform, (ii) decompose that overall function into sub-functions that can be arranged in various function structures, (iii) assign physical components to perform the sub-functions, and (iv) structure those components to compose the overall system (Hubka, 1982; Hubka, Andreasen, & Eder, 1988; Pahl & Beitz, 1984). This process can be represented with a pair of matched hierarchies (see Figure 1): there is an overall function which branches into ever finer-grained sub-functions (the function hierarchy); these sub-functions directly correspond with a set of physical sub-systems which combine into ever larger sub-systems (the physical hierarchy) until a single overall system results (Umeda and Tomiyama, 1997: p. 43; also see Chakrabarti & Bligh, 2001: p. 497). Satisfying each sub-function can be viewed as the means by which the function above it (the ends) is achieved, which in