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Towards A Unified Definition of Function

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Abstract. Both natural objects and artifacts have been studied from a variety of perspectives by the different sciences. One issue that has so far resisted philosophical and ontological investigations is the definition of a general notion of function capable of making sense of the functions attributed to natural objects, such as biological organisms, as well as of the functions attributed to artifacts, such as (designed) tools.

The paper starts from the notions of role and context to study a definition already used to define artifact functions. The clarification of types of functional contexts and of the role of intentionality in defining function leads to a new proposal that applies to functions of natural objects as well as of artifacts. Finally, we evaluate our proposal against some desiderata discussed in the literature.

Keywords. function, context, role, biological function, engineering function

Introduction

In this paper we address a challenge that has attracted much attention recently, namely, to provide a unified definition for biological and (technical) artifact functions. Briefly said, our proposal starts from an existing definition of artifact function in [13,14], which relies on intentionality via the notion of goal, and generalizes it to a new notion for both biological and artifact functions. This result is obtained by analyzing and clarifying the role of intentionality in the original definition.

The term intentionality is here used in the standard meaning it has in the philosophical tradition as the power of minds to be about, to represent, or to stand for, things, properties and states of affairs [11]. In the simple case, which is what interests us here, intentionality may be directed to, say, a physical object, i.e. something which is not mental as in the BDI approach [5] where a goal is a *state to be achieved*.[2]

In this domain, we propose to distinguish at least two uses of intentionality: one use of intentionality has to do with the choice of the system which is the subject of the functional study, and the other use of intentionality has to do with the choice of a behavior and a state (as the goal) of the system. We aim to show that the first use of intentionality for artifact functions is not really a problem when searching for a unified notion of function since this very use of intentionality is already admitted in theories of biological

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[2] More precisely, a strategic interest of an actor, i.e., an agent playing a role. Note that in these approaches the notion of agent is broad, spanning both people and software, in particular it is not limited to intentional agents.

functions, as we will see. On the other hand, the second use of intentionality, that is, when intentionality is used to provide the system's goal, can be weakened in theories of artifact functions. With this analysis, a new formalization of an existing definition of artifact function will arise. It can be then observed that biological functions are equally captured by this new formalization.

The paper is organized as follows. Section 1 presents the notion of behavior used in this paper and Section 2 focuses on function contexts and their separation in systemic, user and design contexts. Section 3 highlights the relevance of behaviors in function contexts and the next section, Section 4, looks at the relationship between systemic contexts and objects, and between user contexts and events. Section 5 gives our definition of function. This definition is used to discuss essential vs accidental functions in Section 6. The definition of function is evaluated in Section 7. Section 8 discusses related work, and the final section adds some concluding remarks.

1. Behavior

Our definition of function builds on top of two other notions that we take as primitive, namely, behavior and context. Behaviors form a subcategory of Process as in the approach presented in [8] and are fully exploited in the Yamato ontology.[3]

A process in Yamato is a temporal entity that captures instantaneous change. Suppose we fix an event, a spatio-temporal entity, in which a person walks from A to B during a period of time $[t_0, t_1]$. While the event takes place, i.e. during the walk of the person during $[t_0, t_1]$, the person undergoes a continuous change, namely, what the person (entity) experiences at each instant from t_0 to t_1. In natural language we use expression "the person is walking" to indicate this ongoing change. Yamato calls it a process and opposes it to the walk event, the latter being a temporally extended entity. One can think of the process as the continuous change that, instant after instant, builds up the walk event from t_o to t_1; and the event as the god's view of all changes that happen to the person during the whole period $[t_0, t_1]$.

When dealing with physical objects, as we do here, the behavior can be seen as the evolution of the values of the object's qualities since these entirely describe the evolution of the object's status. Clearly, these changes are determined by the evolving interaction between the object and the environment. This perspective leads to classify behavior as a type of process.

Let us consider a technical device. Engineers describe the behavior of a device by looking at how the device is affected and how it affects quality values in the elements it interacts with. Note, however, that engineers are usually interested in some of the qualities affected by the device, and focus on those only. Our proposal aims to generalize this perspective to make it applicable to any physical object, including natural objects like biological systems. This generalization is justified by the ontological assumption that any interaction between the physical object and the physical environment is described by changes in the values of some physical qualities. We thus conclude that the behavior of a physical object is the process identified by the input-output change of the whole set of physical qualities that can be affected by that object.

[3] http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/upperOnto.htm

2. Function Context

The second notion we rely upon is that of context. Context has been largely debated in different domains like phycology and sociology [19] or logic and reasoning [9], but no shared view has emerged in the literature. Without aiming at explaining the notion, informally we assume that a context is a complex entity which depends on either an event or an object. In particular, we will assume that whenever we select an event or an object, by the same act we also select a context. For example, an event like a soccer game provides a context to talk about roles like players and events like scoring. An object like a house provides a context to talk about other objects like walls and doors, and events like entering and heating. Analogously, social objects like schools, provide a context to talk about social roles like teachers and students, as well as social events like lectures and exams. In our view contexts and roles are indeed mutually dependent entities: a role does not exist if not in a context and a context cannot exist without identifying some role [17].

For what concerns us, we will concentrate on a more specific notion called *function context*. Function contexts are themselves partitioned in three subtypes: systemic context, use context and design context. We claim that these specialized categories suffice to define the different types of functions.

A *systemic context* is the context associated with a physical object, namely the system, which comprises one or more components and is seen as an integral whole. The system can be fairly simple like a hammer understood as the combination of the handle and the head (including their relationship and structure), or quite complex like the environmental water circulatory system. In both cases, the systemic context includes the system, its components, the nested structure of subsystems formed by the components, selected behaviors for each component and one selected behavior for the system itself. Furthermore, the systemic context identifies one component whose function is being determined in the context. (Note that the behaviors identified in the systemic context introduce some further reciprocal constraints that we will describe in the next session.)

A *use context* is the context associated with an event and is fixed by an intentional agent participating in the event and whose aim it to reach his/her (intentional) goals. Note that we call intentional goal a state of affairs desired by an intentional agent. Assume we aim to determine the function of a device like a hammer in a use context relative to an event like, say, an agent with dirty hands that opens a door by pushing it with the hammer so to avoid making the door dirty. This context provides the object (hammer), the goals (the state in which the door is open and clean), the agent (which coincides with the user) and the relevant environment elements (clean door, being on one side of the door, dirty hands etc).

The *design context* exists in relation to designed objects and comprises a designer, a designed object and the specification of some *use situations*. We distinguish two kinds of use situations. In the first case, a use situation is, roughly, an event that satisfies the constraints posit by the designer and in which the object is used in a way that matches the designer's intention. In this case, the use situation reminds of a use context as described earlier. In the other case, a use situation is a complex entity of which the designed object is taken as a component. A hammer, as a designed object, is related to a use situation of the first kind. A pump, as a designed object, to the latter. We call the use situations of the second kind *envisioned systemic contexts* since they are like systemic contexts if we disregard the designer's intention. The specification of these two kinds of use situations is also identified by the designed object itself in virtue of its properties.[4]

From this brief presentation, it is clear that the design context differs in kind from the systemic and use contexts. For example, if a designer designed an object with the specification of hammering nails into pieces of wood as use situation, then the designed object is properly identified as (having the essential properties of) a claw hammer. The designed object is then expected to satisfy whatever required by the design context, and the designer's intention determines its function. Yet, the design context does not identify an event (a token) in which the claw hammer functions as such.

We insist that systemic context, use context and design context differ from ontological and from practical perspectives. The first and the second rely on different ontological categories: systemic contexts are centered on the object category while use contexts on the event category. These both differ from the design context since in the latter case the function is identified by the designer. The three are also ontologically distinguished since the intentionality source in the use context is a participant of the event, namely the user. The intentionality in the design context comes from the designer which does not even participate in the use situation. Finally, the systemic context makes no reference to intentional agents, and thus intentional goals.

However, it would be too harsh to conclude that systemic and use contexts are unrelated. Together they provide flexible and complementary ways to isolate functional information. For instance, systemic contexts can be used to alternatively capture the core elements of a use context. We can see a use context from the viewpoint of a systemic context by taking the object (the device) in the use context as the selected component of the system, the agent (the user) as another component of the system, and the system itself as composed by (at least) the device and the user. The user intention is not part of the resulting systemic context but it turns out that the goal of the user corresponds to the goal determined by the selected behavior of the system. Indeed, one can think of the user's goal as a meta-operator that leads to the selection of the system's behavior. This observation, together with the fact that envisioned systemic contexts roughly correspond to systemic contexts, suggests that systemic contexts are central to the study of functions.

3. The Relationship between Behavior and Context

The pivoting idea in the definition of function we are developing can be summed up as follows: functions are given by the interplay between behaviors and function contexts. Ontologically speaking, the behavior gives the variety of possible changes for a given object; the function context provides the means to isolate a subset of the possible behaviors by filtering out the input-output that are irrelevant with respect to the context. Finally, these selected behaviors in the given context play a *functional role* as discussed later. In [13,14], a technical (actual) function is defined as "a role played by a (device-oriented) behavior in a teleological (function) context". The investigation in this paper exploits this definition.

[4] To be more precise, by designed objects here we mean engineering artifacts as described in [4]. A designed object in this sense is a physical object which undergoes an (intentionally performed) manufacturing phase. Since the manufacturing phase aims to make the object suitable in some use context desired by the designer, by undergoing this phase the object is associated with the specification of such use context(s).

The three function contexts seen above lead to three kinds of functions that we dub *systemic function*, *use function* and *design function*, respectively. Function contexts come in different forms because they provide the information to identify the target function in different ways. Thus, we can restate our goal as follows: to motivate a unified definition of biological and artifact functions by studying the relationships among systemic, use and design functions.

We argue below that the systemic context (and thus the systemic function) plays an essential role to identify a unified definition of function. Instead, the design context helps in two aspects: to distinguish between essential and accidental functions, and to show the similarity between biological and artifact functions. Use functions are largely discussed in the literature and a general notion of function should be able to account for them as well. So, a unified definition of function has to be capable to cover use functions as well as biological and artifact functions. In what follows we concentrate on the fairly new notion of systemic context and describe how it brings into the picture the needed information for the function definition.

As said, a systemic context includes a system, to be seen as a whole object, with a (typically partial) list of its components or subsystems. It also provides one of the system's behaviors and a selection of the subsystems' and the components' behaviors. As anticipated in the description of the systemic context, the structural relationships between system and components impose further constraints on the listed behaviors: the selected behavior of the system has to be 'matched' by the behavior of its subsystems and components in the sense that: the selected system's behavior is caused (is physically or otherwise explained) by some of the component's and subsystems' selected behaviors. We already anticipated that the object performing the function in a systemic context is one of the components while, differently from use and design contexts, there is no intentional agent. This latter point is of primary relevance: in the use context (the design context) the agent (the designer, respectively) brings about the intentional goal. In the systemic context the role of a goal is taken by the selected behavior of the system.

Let X, Y, Z, W be a set of components and/or subsystems in a systemic context for the system S such that X, Y and Z cover the input-output relationships relative to the selected behavior of S. Let X be the target component whose function in the given systemic context is to be determined (Fig. 1). By definition of systemic context, S's behavior corresponds to the combination of some given behaviors of X, Y and Z, and we say that the goal of X relative to the selected behavior of S is to *contribute in* X, Y *and* Z to the realization of S's selected behavior.

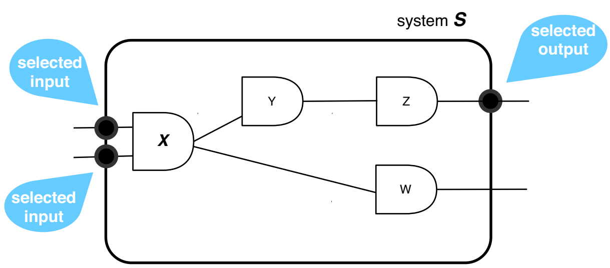

Figure 1. A system S, its components and selected input-output (circled).

Let us look at an example largely discussed in the literature, e.g. [21,20]: the function of the heart in the human body. The systemic context (C) of the human body system (S) provides the chosen components among which the heart (X), selected as the object whose function is to be determined. For the sake of the example, let us assume that we have two more components: the artery subsystem (Y) and the kidneys (Z). The selected behavior of the human body S is the blood circulation and the selected behaviors of the heart are the pressuring blood and the making sound. Since by physical laws the blood circulation is realized via pressuring the blood in the arteries to which the heart is connected, we conclude that the heart, via the selected pressuring behavior, contributes to the realization of the selected behavior of S.

Analogously, let the systemic context C' be like C except that the selected behavior of S is the sound made by S. This time we conclude that the heart, via this making sound behavior, contributes to the realization of the selected behavior (making sound) of S.

As we have seen, the systemic context filters out the components that do not contribute to the system's behavior, e.g. Z in the previous examples, and preserves only the relevant behaviors of the contributing components (pressuring blood in the first example and making sound in the latter). The component's contribution is mandated by physical laws in the described examples but systemic contexts are not restricted to physical laws in general. For a different example involving social laws, consider the behavior of a person in the context of a school. When the person has some connection to the school, say, s/he plays the role of teacher, the systemic context considers only the relationships relevant to this role, e.g., complying with the schedule, giving lectures and assigning homework, and leaves aside things like feeding pets and skiing. The latter behaviors are behaviors of the person, of course, but are not contributing to the system's behavior.

4. Systems and the Systemic Contexts

In general a system does not provide enough information to identify a unique systemic context; some elements, typically goal and focussed component, need to be identified counting on further information (the system contains no explicit intentional agent that provides the context's goal). As we have seen in the introduction of systemic contexts, the relationship between a system and a system context requires: a selected behavior of the system, selected behaviors of the given components and subsystems, and also the identification of the component whose function is to be determined. Let us call the latter the *functional component*. The selected behavior of the system provides the goal of the functional component, say X, within the systemic context as seen in the previous heart/human body example.

Let us look at this point more precisely. Once the system S with relevant components $X_1, X_2, \ldots$ (among which X) is fixed, what we need is a selected behavior of S. Let us say this behavior is the relationship between input I_n (a set of S's qualities) and output O_n (also a set of S's qualities). The function of the component X is to contribute to the manifestation of the selected behavior of S and it is in this sense that the selected behavior of S provides the goal of the systemic context. The reader should notice that our use of the term goal, while natural from the given perspective, generalizes the standard notion: the goal in the systemic context is not the goal of an agent and, more precisely, it is *not* an intentional goal.[5] In systemic contexts, this term points at the role of the system's selected behavior, a role that corresponds to the user's goal in the use context.

The previous information plus knowledge of physical and social laws leads to isolate the smallest combination of components that has as input and output at least I_n and O_n. In other words, one looks for a substructure X^* of S such that the selected behavior of S is a behavior of X^* or part of a behavior of X^*. If X, the functional component, is not part of X^* or none of X's selected behaviors contributes to the achievement of the input/output of X^*, then X's behavior(s) does not play a function role with respect to the systemic context's goal, i.e. with respect to the selected behavior of S and X has no function in that context. Instead, if X is part of X^* and some of its selected behaviors contribute to the achievement of the desired input/output of X^*, then X's behavior(s) does play a function role in S with respect to the goal of the systemic context, the behavior thus realizes a function.

To conclude, the relationship between the system and the systemic context is partially determined by the structure of the system itself and needs to be completed with new elements (or selections) as described.

5. A Unified Definition of Function

As claimed, the ultimate goal of this paper is to propose a unified definition of artifact functions and biological functions. Usually, this means to find a generalization of these two kinds of function and argue that it forms the *common core* for the notions so that each one is obtained as a direct specialization of it. The identification of such a core-notion is the aim of this section. In doing this, we start from the three kinds of functions isolated earlier, namely systemic, use and design function.

We said that functions are roles played by behaviors in a function context. We will refer to these roles as *functional roles*. The distinction among the three kinds of function context is clearly the crucial element here. These function contexts differ, among other things, in the way they identify the functional role. In the case of systemic contexts, the functional role is identified by the goal of a subsystem. In the case of design contexts, the functional role is determined by the designer's intention. Finally, in the case of the use context, the determination is given by the user's intention. It is now time to formalize the corresponding function types.

Definition 1 (Systemic Function) *Given a system S, an object A and a systemic context C, we say that A performs a* systemic function *in C when:*
C is a systemic context for S and according to C, A is a component of a subsystem of S, the goal of this subsystem is to realize the goal of C, and some behaviors of A play the (functional) role determined by C.

Regarding Definition 1, note that the goal of C is, by definition of systemic context, the selected behavior of S and that by playing the role determined by C the behaviors

[5] It is clear that the system's behavior, which is part of the systemic context, has been selected somehow, and this selection can be the result of an intentional choice. For instance, the standard heart/human body example is thus selected by researchers aiming to understand the heart function in the human body system. The point we are making is that the systemic context, differing from the design and use contexts, does not (need to) contain nor refer to an agent in charge of this choice.

of A contribute to the realization of C's goal. As discussed in Section 2, the systemic context does not refer to any intentional agent and thus intentional goal. So, at the instance level, some instances of systemic function may include intentionality and others do not. Recall that the term 'goal' points to a state to be achieved (by the corresponding component under consideration), i.e. it refers to the realization of a behavior.

Secondly, we define use function based on the use context as follows:

Definition 2 (Use Function) *Given an object A, an agent B and a use context C, we say that A performs a* use function *in C for B when:*
A and B participate in the event E (the performance) associated with C, B plays the user role from C's perspective, and the behaviors of A in E, as selected by C, play the (functional) role determined by B's goal(s) in E.

As discussed in the last paragraph of Section 2, a use context can be interpreted in terms of a systemic context by considering a system S consisting of the object A and the agent B. In other words, the use function is seen as a systemic function where the systemic context's goal is provided by a special component of the system, namely the user. Thus, the use function can be interpreted as a specialized (sub-) type of the systemic function.

The notion of use function is important for a unified notion of function. It is justified by the fact that even natural things have functions in some contexts and by the notion of accidental function as discussed in the next section. Use functions are not intrinsic to the entity but are, so to speak, created by the users.

Next, we define the notion of design function, based on the design context, by combining the previous definitions.

Definition 3 (Design Function) *Given an object A, a designer D and a design context C for D, we say that A performs a* design function *in a situation*[6] *that satisfies C's requirements when:*
A is designed by D and

a) if the situation is an event, then A performs a use function in this event for the user (also a participant to the event) determined by C;
b) if the situation is a complex entity S, then A performs a systemic function for the system S whose selected behavior is determined by D.

The main difference between the use function and the design function is the provider of the intentionality. A design context comprises an envisioned use context, or an envisioned systemic context, plus the designer's intention. Thus, the design function is regarded as a systemic function where the systemic context's goal is provided by the designer based on his/her intention. So, the design function is the systemic function as determined by the designer's intention. As before, it turns out that design functions form a (sub-) type of systemic function.

We now have all the elements to explain the (unified) notion of function that includes both artifact and biological functions. A biological function is identified by systemic

[6]"Situation" is here used to denote both envisioned use context and systemic context.

contexts in which no intentionality is involved. Since the systemic context category is neutral with respect to intentionality, it subsumes both systemic contexts with intentionality and systemic contexts without intentionality. It follows that biological functions are a specialization of systemic functions. The function of an artifact (better, an engineering artifact as in [4]) is instead designed by a designer who intended the artifact to behave in a certain way in some given use situations. So, the artifact function is a design function, that is, a specialization of systemic function as well. Note that the argument about biological and artifact functions does not mention use functions. Indeed, use functions do not match the biological/artifact divide. It is, however, an important notion for the unified function. Natural entities can have use functions, e.g. using a tree to get shade. On the other hand, a use function of an artifact may coincide with a design function for that artifact. Of course, use functions also comprise accidental functions (see below).

Let us sum up this view using the heart/human body example. One can claim that the function 'to pump blood' is common to a natural heart and to an artificial heart in the blood circulatory system. This function is a systemic function since the behavior of both these objects contributes to the circulation of the blood in the circulatory system of the human body. This function is not a design function for the natural heart since there is no design context for this heart. It is instead a design function for the artificial heart since the goal of the designer is that the behavior of this device contributes to the circulation of blood in the circulatory system of a human body.

We conclude that, by accepting the role-base view on functions, the notion of systemic function does furnish the core for all types of function discussed in this paper. We have thus completed our search for a unified definition of function from which both artifact and biological functions can be obtained by specialization.

6. Essential and Accidental Functions

Most proposals in the literature take the distinction between essential and accidental functions seriously, and explicitly separate function ascription from performance. For these authors some objects seem to have a special dependence relation with some functions. Such functions are deemed essential to them because the existence of these objects is ontologically connected to the performance of those functions. This view is often motivated by the study of biological organisms, like human and animal bodies, which often seem to come with specific contexts unique to them.

Considering our function contexts, it should be fairly clear that a use context does not deal with the distinction between essential and accidental functions. In some use contexts, a hammer is used to open a door; in others to hammer nails. From the use context viewpoint, these are just functions and nothing suggests a special relationship between the hammer and the opening or the hammering.

In the case of artifacts, the design context provides information on the reason an object, the artifact, has been designed. Thus, the design context binds an object to some use situations which determine a preferred function (or functions) for the object itself. Indeed, the object is intended to perform the function that the designer envisioned in the design context. This historical and, so to speak, generative dependence between the object and the designer's intended function distinguishes the latter as having a causal role for the object's existence, and thus it is taken to be essential for its existence. Note here that this observation is based on the assumption that the use situation matches the actual use context and, more generally, the actual systemic context. Therefore we can conclude that the essential function(s) of a designed object is consistently explained within the systemic view.

In the case of natural entities, functions are evaluated without reference to intentional goals. Only the systemic context determines the function of a component in this sense. Thus, the distinction between essential and accidental functions with respect to these entities takes place within systemic contexts only. From the systemic viewpoint, the pumping blood function of the heart is meaningful only in the context of a system and only if the heart is a component that contributes to the system's behavior in the way previously described. Thus, the pumping blood function is performed with respect to the blood circulatory system and might not be such in other systemic contexts, e.g. the reproduction system. Not all the systemic contexts are on a par, of course. Essentiality of the systemic functions should be judged according to the existence of contribution to the goal determined by the selected behavior. Therefore, all the systemic functions are essential *with respect to the systemic context.*

Ontologically, the essentiality of a biological function depends on the systemic function; use functions are accidental to organisms. So, the pumping-blood function of a heart is essential in the context of the circulatory system, the sound-making function of a heart is essential in the context of the sound-making behavior of the human body. Note that the sound-making function of a heart is essential only when the sound-making behavior of the human body is selected by the systemic context. This function may seem somewhat odd but it just depends on the selection of the sound-making behavior of the human body. However, being odd or not escapes ontological considerations as discussed in [6, p.762].[7]

The outcome of these observations leads to a triadic classification of functions with respect to an object x. A function F is *irrelevant* to x when x cannot perform F in any function context. A function F is *relevant* to x when there is a function context in which x plays function F. A function F is *essential* to x when it is relevant and the function context is a design context for object x or a systemic context (but not use context) for x. The remaining relevant functions of x are simply accidental functions.

7. Evaluation of the Unified Definition

In this section we evaluate our proposal against some general requirements discussed in the literature. In particular, we follow Artiga's list of desiderata as collected in [2]. Our discussion of these points is twofold: it shows how our approach does justice of important intuitions about functions, and provides an indirect comparison with other theories in the literature, for references see [2].

Artiga's desiderata are the result of a discussion mainly about biological functions, but they apply to artifact functions as well. To properly evaluate artifact functions we need to include two further elements: intentionality and the notion of use function. Needless to say, intentionality is the master key to distinguish between biological and artifact functions, and is unavoidable in discussing artifacts' identity. In the philosophical

[7] Sometimes the observation "Most spermatozoids fail to fertilize ova" is taken as a counterexample to the contribution theory of functions. However, success/failure can be established only in the correct context which, in this scenario, is the spermatozoid meeting an unfertilized ovum. Therefore, the case of a spermatozoid that reaches an ovum already fertilized and fails to fertilize it, cannot be taken as a counterexample.

discussion on biological functions, use functions seem to have no place. Even accidental functions are undesired elements, so that stating the difference between essential and accidental functions is of primary importance in this sector. In the discussion on artifact functions, however, one cannot avoid dealing with use functions: simply there are too many relevant functions which exist in virtue of being induced by an object's user (independently of the object's nature).

Leaving aside intentionality and use functions, which have been discussed earlier, we now concentrate on Artiga's desiderata rephrased, for the sake of the discussion, as follows:

a) (Naturalized) Teleological property: *The attribution of a function to an object, points at some activity that explains why the object exists.*
b) (Naturalized) Normativity: *An object's function is something an object is supposed to do, in the sense that livers are supposed to filter wastes from blood.*
c) Performance: *The object's function is determined by the object's current performances.*
d) Essential and accidental functions: *An object's function is appropriately distinguished from an object's accidental effects.*

From the perspective of the definition in Section 5, it follows that:

a) (Naturalized) Teleological property: We have seen that all functions are fundamentally systemic function. The object which realizes the systemic function exists to contribute to the systemic goal specified by the systemic context. Each systemic function is thus teleological although relatively to a systemic context. The reliability of the choice of the systemic context depends on our domain knowledge and is thus expected to increase as science advance. Of course, in the case of design functions, there is a further teleological aspect related to the object's "activity" in the envisioned use context.
b) (Naturalized) Normativity: This desideratum refers to an expected performance specified by the functional role and determined by the systemic context. In our approach, functions do not inhere in the object and are related to it via the notion of functional role, that is, via a temporary and non-essential property of the entity playing it. The functional role, played by a behavior of the object, indicates what the object is expected to do.
c) Performance: This is a direct outcome of the proposed definition since any systemic function, including design functions, depends on the behavior of the object in a specific context. The context is either an actual event or what is envisioned that includes the actual behavior of the component of a system.
d) Distinction between essential and accidental functions: This issue has been addressed in Section 6. Here we add some further explanation. In the case of biological functions, all systemic functions which contribute to keeping the overall system exhibiting its behavior are essential. At the same time, all use functions are accidental: there is no intrinsic reason for a biological organism to be used by some intentional agent. Thus the idea of use function helps to make order in debated examples like the glasses-holding function of a nose [2]. The glasses-holding function of the nose is a use function, hence it is accidental. Our definition clearly distinguishes accidental functions like this from the essential (systemic) function of the nose, namely letting air enter

into the body. Lastly, in the case of artifact functions one can easily determine which, among all functions, is essential by looking at the designer's goal.

8. Related Work

In the previous section we presented the reasons why our theory satisfies the Artiga's desiderata. That discussion indirectly clarified our stand with respect to important issues discussed in the literature. In this section, we add a few observations by comparing our work to other theories. Many definitions of function have been proposed in engineering, philosophy and ontology research as discussed in these surveys [7,18,20]. Our theory, built upon the notion of systemic function, falls within the so-called *contribution theory* (e.g., [3,6]) rather than other approaches such as the etiological theory. The most important difference between our theory and other contribution theories is that we aim at clarifying how the goal is determined in terms of the kinds of context, a clarification missing in both [3] and [6], and at identifying the sub-types of the systemic function based on them. We also do not identify functions with properties (capacities) of an entity like in Cummins's theory [6], or with dispositions to contribute to the system like in Johansson et al.'s definition of biological functions [12].

Houkes and Vermaas propose a different set of desiderata for technical functions [10]: (1) proper and accidental, (2) malfunctioning, (3) measure of support, and (4) innovative functions. The first item is also in Artiga's list. Our systemic function satisfies (2) because of the normativity desideratum, and (3) because of its nature based on contribution. Finally, (4) is satisfied since our proposal puts no restriction on innovativeness of functions.

In addition, much research has been carried out on comparing biological functions and artificial functions (see [16]), and some attempts to unify them has been proposed. For instance, Arp and Smith [1], among others, define biological function and artifact function as a sub-type of a (generic) function. Their definition of generic function mainly relies on answers to naive questions like "how does it come into being?". Krohs [15] exploits a different intuition: the unification is based on the concept of function in terms of systemic roles of type-fixed components, where the type-fixation is a source of normativity. Our approach differs from both since based on the notion of context and not relying on the entity's type.

9. Discussion and concluding remarks

As discussed above, our definition belongs to the so-called contribution (or dispositional) approach to functions. So, it might be a bit surprising that it satisfies Artiga's teleological, normativity and essentiality desiderata. The reason why we can achieve this result is due to several aspects. We discuss them below.

In order to cover both biological and artifact functions, we explicitly introduced the notion of context in which functions can be performed. In the literature on biological functions, it seems to be implicitly assumed that each organism has its own inherent context to perform its function, so we find claims such as: *This is "the" function of this organism*, and hence function definition of an organism tends to be mixed to function identification of an organism. The explicit introduction of the notion of context enabled us to make the notion of function relative to its context and to understand biological functions as a special case of artifact functions, where a context is fixed for reasons which might be explained using biological knowledge. This allows us to talk about function conditionally on the assumed context, and this is why our definition satisfies the teleological desideratum.

Note also that our teleological explanation is naturalized in spite of the fact that the goal is set by the systemic context. The focus on the selection of the behavior of the overall system, which includes the component whose function is under consideration, explains why function identification is clearly different from function definition in our approach. After all, the former depends on our knowledge, the latter does not. For example, when apoptosis is required in an organism, a specific function context needs to be assumed as “the” systemic context . Thus, the actual identification of apoptosis forces the choice of a specific context. Instead, it suffices to hypotetically consider such a situation to explain the definition of the apoptosis function.

Note, however, that our definition remains open; if one makes the assumption that there is “the” context (without further specifications) for an entity, then we can refer to “the” function (without further specifications) for that entity. In other words, we could say that we loosened the desideratum which originally requires to identify “the” function of any organism. In fact, we adopt the view that to understand any particular function one has to rely on some domain knowledge (a rough form of context) and that no domain knowledge can be taken to be “the right context” for a given object.

Another point is that a function, as we define it, is not something that exists in the object under consideration. Our definition claims that what inheres in the object is not the function itself but some capacity to perform the behavior which can play the specified functional role. The pivoting idea is that of functional role; it represents what the object is expected to do when it is put in the function context. This aspect contributed to satisfying the normativity desideratum. The separation between functional role and behavior heavily relies on the dependence of function on context. If the context was embedded in the object combined with the behavior, then the previous dependence would not be realized. Apparently, however, various pieces of contextual information cannot inhere in any object.

Our definition satisfies the essentiality desideratum thanks to the introduction of the notion of use function. The notion of use function enables us to claim that all the systemic functions are essential to the components under their systemic contexts and that all use functions are accidental to all natural objects. These three notions, i.e., the notions of context, functional role and use function, emerged in the engineering domain where one cannot avoid to talk about designers’ and users’ intention. The latter is crucial since users can use anything in any way they want, which provides various, sometimes unexpected contexts for the objects.

Finally, our definition copes with malfunction and related notions thanks to the separation between functional role and behavior. The main difficulty of other approaches within the contribution theory is the assumption that a function inheres in an object, and hence malfunctioning cannot be explained. In our definition, on the other hand, the functional role, derived from the goal in the systemic context, is independent of the object, and enables us to talk about what the malfunctioning object is expect to do: A component in a system is said to malfunction (with respect to a given function of the system) if its behavior in the function context for the system does not satisfy the expectation (the normativity) fixed by the functional role for that context. Of course, degrees of malfunctions can be distinguished by qualifying the mismatch. We do not have space to discuss this further but observe that this distinction between functional role and behavior, brought into the picture in the discussion of the normativity desideratum, is fundamental to understand our general approach.

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