Explaining and Relating Different Engineering Models of Functional Decomposition

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Abstract

In this paper I analyze the use of different models of functional decomposition in engineering design. I consider models that refer to sets of desired behavior-functions, to sets of desired effect-functions, and ones that refer to sets of purpose-functions. It is argued that the choice for a particular model is affected by whether or not its construction will be based on known function-structure connections for the functions in the model or on known behavior-structure relations that implement the functions in the model. It is then argued that whether or not such knowledge is taken into account is affected by specific design objectives. Finally, I thus argue that the choice for and suitability of particular models of functional decomposition depends on the design objectives for which these models are employed. Based on this result, it is concluded that the co-existence of different functional decomposition-models has engineering value, defining the remaining task to relate them. To this end, a strategy is proposed for relating different models. The above analysis is focused on three approaches that advance particular models of functional decomposition: the Functional Basis approach in which models refer to sets of desired behavior-functions, the Functional Interpretation Language approach in which models refer to sets of desired effect-functions, and the Dual Stage approach in which models refer to sets of purpose-functions.

Keywords

functional decomposition-model; design objective; design knowledge.

As evidenced by a recent review of Erden et al. (2008), engineering design research has produced an impressive number of functional modeling approaches. In these approaches a variety of definitions of functions, representation schemes for functions, and strategies and representation schemes for the decomposition of functions into sub functions are formulated. It is however acknowledged in the literature that this richness of different conceptualizations has its price: it can lead to cross-communication problems between engineers working with different functional frameworks (e.g. Rosenman & Gero, 1999; Deng, 2002). In the review given by Erden et al. (2008) the authors state, for instance, that not all reviewed approaches are compatible with one another. This sets a research challenge for establishing human and automated communication across functional frameworks. Different responses are given in the engineering literature to the diversity of functional frameworks. Erden et al. (2008) suggest that incompatibilities between approaches are due to different educational backgrounds and different application domains they are aimed at. Yet, at the same time, these authors aim with their review to develop a common framework for functional modeling that rises above the domains. Achieving this aim however suggests the discarding of a number of approaches for, otherwise, it seems that due to these incompatibilities the envisioned framework cannot provide the desired common frame that transcends particular application domains, and functional modeling thus will remain domain-specific (cf. Vermaas, 2009). Other authors seem to acknowledge the worth of keeping different functional frameworks side-by-side, considering them useful for different applications, yet at the same time they voice preferences for particular ones (cf. Umeda et al., 1996; Deng, 2002).

In this paper I evaluate the merits of adopting a single and common framework for functional modeling. The benefits of adopting such a common framework are immediately obvious: cross-communication problems will presumably be solved. However, adopting a common framework may at the same time narrow down the application scope of functional modeling. I will assess by means of a case study how a single and common modeling framework fares when employed in different application domains. Focusing this analysis on models of functional decomposition, graphical representations of organized sets of functions, I identify three particular notions of functional decomposition-model and three specific engineering objectives that are advanced in the functional modeling literature. These models and objectives are derived from: the Functional Basis (FB) approach (Stone & Wood, 2000), the Functional Interpretation Language (FIL) approach (Price, 1998; Bell, Snooke, & Price, 2007), and the Dual Stage (DS) approach (Deng, Tor, & Britton, 2000a; Deng, Tor, & Britton, 2000b; Deng, 2002). Framed in the context of this case, this paper addresses the research question whether the use of one of these three models of functional decomposition is suited for achieving each of the three objectives. This case study shows that, rather than favoring a single framework-proposal (and displacing a number of models), particular models are suited for specific objectives, implying the engineering value of keeping different models of functional decomposition side-by-side. Given this result, the challenge then becomes — with an eye to the cross-communication context mentioned earlier — to relate different models of functional decomposition. This paper also briefly outlines a strategy to meet this challenge.

I start my investigation of the different notions of functional decomposition-model in terms of an analysis advanced by Vermaas (2009). His analysis shows that specific meanings of the concept of technical function are used in engineering to advance specific descriptions of technical devices. Since these descriptions are all useful to engineering, he thus explains why the concept of function is used with more than one meaning in the field. He identifies three archetypical meanings of the concept of technical function: desired behavior, desired effect of behavior, and purpose. Using this analysis, I argue that FB models refer to sets of behavior-functions, FIL models refer to sets of effect-functions, and that DS models refer to sets of purpose-functions. In the research of Vermaas (2009), the choice for advancing a specific meaning of the concept of function, apart from the connection between a specific function meaning and a specific description of a technical device, is a question left implicit. In the case of functional decomposition, it is argued here that (i) the choice for a particular model is affected by whether or not its construction will be based on known function-structure connections, as laid down in engineering knowledge bases, for the functions in the model, and that (ii) whether or not such knowledge is considered is affected by specific design objectives that engineers aim to achieve with their models of functional decomposition.

This research is conceptual and example-based. It focuses on the internal structure of the FB, FIL, and DS approaches, in particular the use of knowledge bases. Empirical examples of functional decomposition-models as specified in these approaches are analyzed, compared, and used as demonstration. This paper is organized as follows. The account of Vermaas (2009) is introduced in section 1. Different models of functional decomposition are discussed in section 2. Design objectives and the use of design knowledge bases are analyzed in section 3. Conclusions are given in Section 4.

1. Simplifying full descriptions of technical devices: relating goal to behavior and/or structure in different ways

Vermaas (2009) has presented an analysis of the flexible meaning of the concept of function as it is used in engineering. This analysis is developed in terms of the notions of a full and a simplified description of a technical device. Vermaas identifies five key concepts in full descriptions of technical devices (see Figure 1): *goals* of agents that refer to states in the world that agents desire to realize by using devices; *actions* that refer to intentional behaviors that agents carry out when using devices; *functions* that refer to desired roles played by devices; *behaviors* that refer to physicochemical state changes of devices; and *structures* that refer to the physicochemical materials and fields of devices, their configurations, and their interactions.

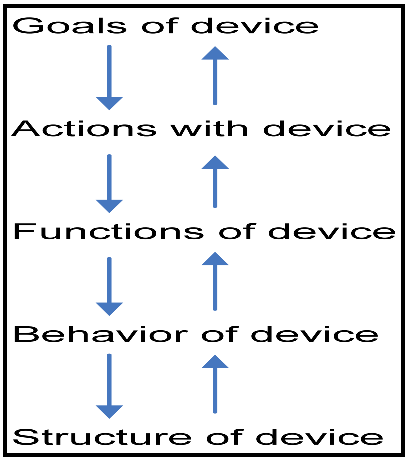

Figure 1 Full description of a technical device in terms of five key concepts (adopted from Vermaas, 2009)

Vermaas asserts that the concept of function is used with different meanings and that this flexibility affords different ways in which such full descriptions of technical devices can be simplified. Full descriptions in terms of the five key concepts are elaborate, and in particular engineering settings it makes sense to simplify them by “by-passing” one or more of the key concepts. Vermaas (2009) demonstrates this by-passing of certain key-concepts in terms of three approaches toward the modeling of or reasoning with functions, each advancing a different meaning of the concept of function: the FB-approach of Stone and Wood (2000), the Multilevel Flow (MFM) approach of Lind (1994), and the Function-Behavior-Structure (FBS) approach of Gero (1990).

Vermaas (2009) argues that in the FB approach, the concepts of action and behavior are “by-passed” and that the concept of function is used in its meaning of *desired behavior* (by specifying the role a device should play in terms of its behavior) to relate goals to structure (see Figure 2). FB-functions are modeled as operations-on-material, energy, or signal flows. Vermaas argues that these descriptions refer to physical behaviors since they represent conversions of matter and/or energy in which the input quantity matches the output quantity, meeting physical conservation laws. A function of an electric screwdriver, for instance, that is described as ‘converting electricity into torque and heat’ (Stone & Wood, 2000) in which the energy of the electricity equals the sum of the energies of heat and torque. In the FB approach, the concept of behavior is thus bypassed and the concept of function is instead used to refer to behavior(s). Vermaas asserts that in the MFM approach the key concept of action is by-passed but not the concept of behavior (see Figure 2). And he argues that in this approach the concept of function is used in its meaning of *desired effect of behavior* (by specifying the role of the device in terms of the effects of the device’s behavior) to relate goals to behavior. Functions in MFM are represented in terms of operations and flows, and may be represented in terms of only input or output flows. A function example may be, say, ‘producing torque’. This description also refers to (features of) behavior but does not meet conservation laws, referring only to the desired effects of behavior (which makes good sense, since the concept of behavior is used to account for the conservation of matter and energy). His analysis of Gero’s FBS approach further broadens the spectrum of engineering meanings of the concept of function. His analysis of the simplified descriptions advanced in this FBS framework shows that the concept of function may also be used to refer to a *goal* desired by an agent. A function example may be, say, ‘having a rotational force down a shaft’. This description refers to a state of affairs in the world, intended by an agent. Vermaas (2009) considers two ways in which simplified descriptions in this FBS framework may be interpreted, due to the shifting position of Gero on the meaning he ascribes to the concept of function: either as functions as goals to behavior, and then structure, by-passing the concept of action (see Figure 2), or, alternatively, as side-stepping both the concepts of goal and action, and reasoning from functions as desired effects to behavior, and then to structure.

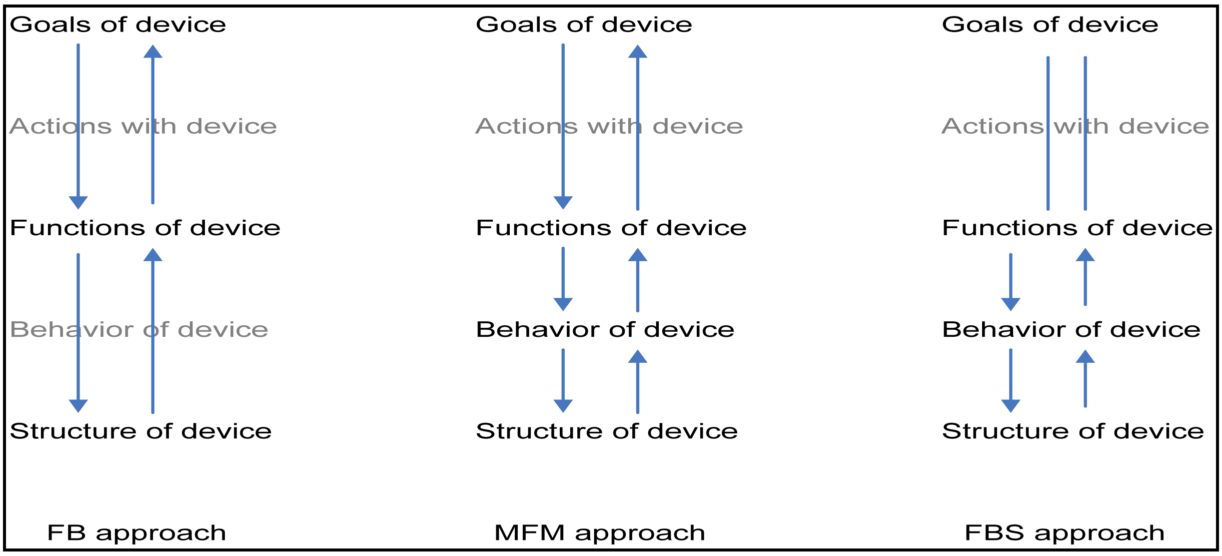

Figure 2 Simplified descriptions advanced in the FB, MFM, and FBS approaches (adopted from Vermaas, 2009)

2. Engineering models of functional decomposition

The foregoing analysis shows that different meanings of the concept of function are employed in relating goals to structure and/or behavior: desired behavior, desired effect, and goal. To distinguish goals of users from goals of designers, I coin the latter purposes. Purpose-function descriptions hence refer to states of affairs in the world, intended by designers. These different meanings of function are given in Table 2.

Behavior-function: desired behavior of a device
Effect-function: desired effect of behavior of a device
Purpose-function: purpose for which a device is designed

Table 1 Three meanings of the concept of function

These three types of functions are also described in models of functional decomposition, graphical representations of organized sets of functions, and the flexibility in the way goals (or designer purposes) are related to structure and/or behavior is also in play in the functional decomposition case. Often, in engineering design, models of functional decomposition (that make up an overall function) are advanced to relate goal (or purpose) to structure (cf. Stone & Wood; Deng et al., 2000a, b; Chakrabarti & Bligh, 2001). In this section I give an analysis of 3 approaches toward functional modeling, each advancing a different model of functional decomposition (fm_D) by which goals (or purposes) are related to structure and/or behavior. These three models are depicted (and abbreviated) in Table 2. Behavior function-fm_D 's are advanced in, for instance, the FB approach, the Systematic approach (Pahl & Beitz, 1988), and the Functional Reasoning approach (Chakrabarti & Bligh, 2001). Effect function- fm_D 's are advanced in, for instance, the FIL approach and the MFM approach. The third notion of purpose function-fm_D is advanced in the DS approach. (I do not consider here the use of the concept of function to refer to a user action, nor the description of such functions in models of functional decomposition. See Van Eck (2010a) for these details).

Functional decomposition model of organized set of behavior-functions (behavior function-fm_D)
Functional decomposition model of organized set of effect-functions (effect function-fm_D)
Functional decomposition model of organized set of purpose-functions (purpose function-fm_D)

Table 2 Three models of functional decomposition

Based on this analysis, I then develop the position in section three that the choice for particular models of functional decomposition is affected by particular design objectives that engineers aim to achieve with them.

2.1. Functional Basis approach

The Functional Basis (FB) approach, developed by Stone and Wood (2000), is an approach to functional modeling that is aimed at supporting the engineering designing of new products in the electro-mechanical domain, as well as the archiving, and communication of functional descriptions of existing products. In the FB approach, an overall product is described in a verb-object form and represented by a black-boxed operation on flows of materials, energies, and signals. A sub function, describing a part of the product's overall task, is also described in a verb-object form but represented by a well-defined basic operation on a well-defined basic flow of materials, energies, or signals. The black-boxed operations on general flows representing product functions are derived from customer needs, and the basic operations and basic flows representing sub functions are laid down in libraries of operations and libraries of flows, together called a *functional basis*.

To support engineering designing, Stone and Wood (2000) present a three-step methodology to develop functional decomposition-models. The method starts with describing a product function in a verb-object form, derived from customer needs and represented by a black-boxed operation on flows of materials, energies, and signals. A chain of operations-on-flows is then specified for each black box input flow, transforming that flow step-by-step into an output flow. These operations-on-flows are to be selected from the FB libraries. Finally, these chains of operations-on-flows are aggregated, completing the model of functional decomposition. Such models are intended to provide a "form-independent blueprint" of the functions of a product-to-be-designed, meaning that no known technical solutions for sub functions – structures – are taken into account during its specification. Not taking such existing function-structure connections into account during specification of a model is intended to support creative, and innovative designs (Stone & Wood, 2000). And in order to support such mappings after completion of a model, the sub functions in it should be small and easily solvable ones. The FB approach currently includes a web-based repository in which functional decompositions of existing products are archived, as well as components counting as design solutions for the sub functions that are part of these decompositions, supporting such mappings systematically.

Functional decomposition-model

Relative to the behavior, effect, and purpose meaning of technical functions, FB-product functions and sub functions can be taken to refer to desired behaviors (which may include their effects) since they represent conversions of matter and/or energy in which the input quantity matches the output quantity, meeting physical conservation laws (cf. Vermaas, 2009; Van Eck, 2009). For instance, the sub function 'converting electricity into torque and heat' (see section 1 and Figure 3). FB-models thus are behavior function-fm_D 's, organized such that the output flows of preceding behavior-functions constitute the input flows of succeeding behavior-functions (Figure 3).

Relative to the five key concepts, the concepts of action and behavior are bypassed and sub functions in FB-fm_D 's relate a goal – customer need – to structures (components as archived in the FB repository).

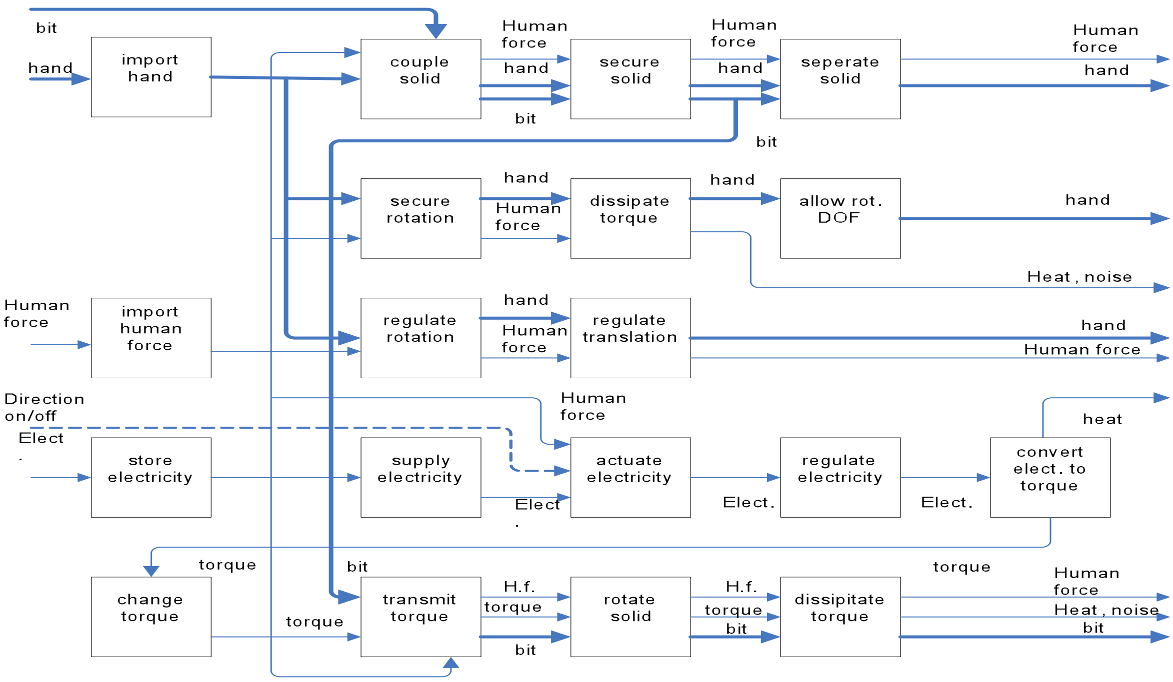

Figure 3 FB behavior function-fm_D of a power screwdriver (Stone & Wood, 2000)

2.2. Functional Interpretation Language approach

The Functional Interpretation Language (FIL) approach (Price, 1998; Bell et al., 2007) is an approach to functional modeling that is aimed at supporting design analysis tasks, such as failure analysis and design verification, mainly in the electro-mechanical domain. In this approach functions of technical devices are taken as and represented by trigger-effect pairs. An overall function is represented in terms of three elements: the “purpose” achieved by the function, the “trigger” of the function, and the “effect” of the function. Purposes in FIL refer to goals that agents aim to achieve when using devices. Triggers and effects in FIL describe the boundaries of a technical device, and are intended as labels that allow linking to relevant properties of its behaviors (in a design analysis context). Sub functions are either represented in terms of these three elements or as combinations of two out of these three elements, depending on the type of device analyzed.

In a design analysis setting, an overall function is decomposed into sub functions when its achievement depends on more than one trigger and effect, or when different trigger-effect pairs can achieve the overall function. In a model of functional decomposition that results, the triggers and effects of the sub functions then replace the trigger and effect (originally) associated with the overall function. Such models allow linking (in a design analysis context) to relevant properties of the behaviors of a technical device, both for tracing the cause of failures and for verifying whether a device’s behavior implements the effects that are desired. This is done by checking the “on/off” states of triggers and effects. For instance, in a functional decomposition-model of a room light-function a sub function is represented by the trigger-effect pair “switch on-light on”. Now, say, if the lamp switch position is “on” (trigger) and the effect “light on” is absent, this sub function has failed (Bell et al., 2007). This trigger-effect relation allows tracing those behavioral properties that cause this failure, say, an electrical short circuit. Such functional decomposition-models describe the (sub) functions of devices of which its required behaviors and structures are known.

Functional decomposition-model
Relative to the behavior, effect, and purpose meaning of technical functions, FIL overall functions and sub functions can be taken to refer to desired effects of behaviors. For instance, the sub function of the room light-function above only refers to the desired effect of the light being on, and not to the behavior due to which this effect is displayed, say, the conversion of electrical energy into light and heat. FIL-models thus are effect function-fm_D 's. (Figure 4)

Relative to the five key concepts, the concept of action is bypassed and sub functions in FIL-fm_D 's relate a goal – FIL-purpose – to behaviors.

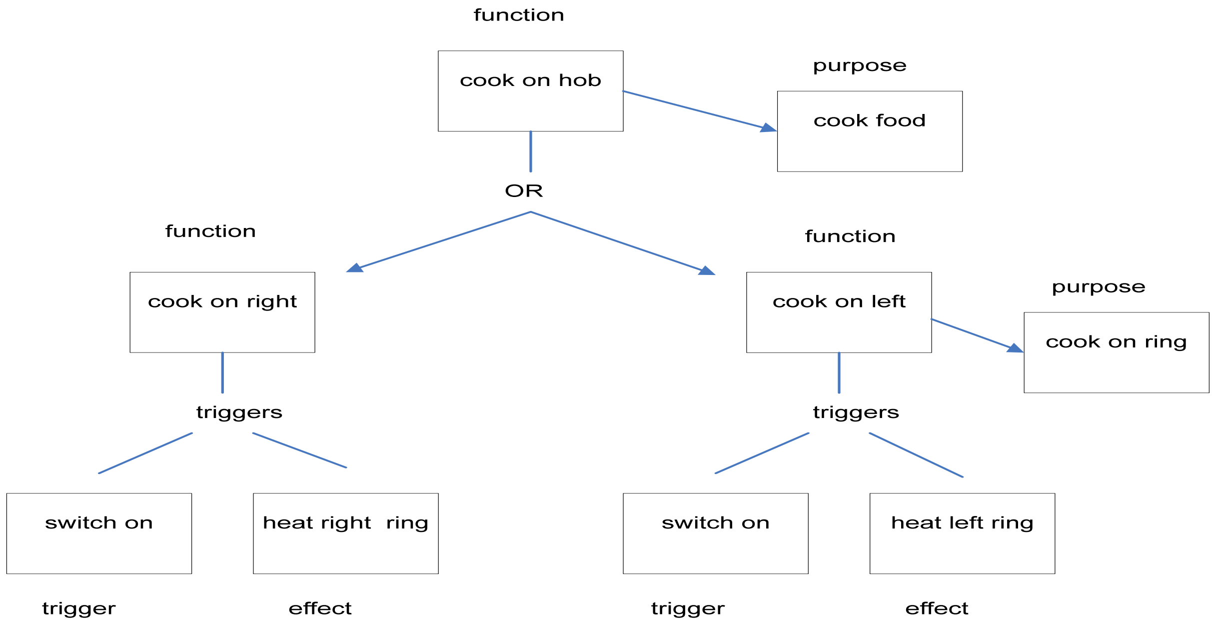

Figure 4 FIL effect function-fm_D of a two ring-cooking hob (Bell et al., 2007)

2.3. Dual Stage approach

The Dual Stage (DS) approach, developed by Deng, Tor, and Britton (2000a, 2000b, 2002), is an approach to functional modeling that is aimed at supporting the engineering designing of products in the mechanical domain. In this approach two types of functions are defined: purpose functions and action functions (Deng, 2002). A purpose function refers to a designer's intention or purpose of a design. An action function is defined as an abstraction of intended behavior. Both types of function are represented by verb-noun descriptions.

To support engineering designing, Deng, Tor, and Britton (2000a, 2000b, 2002) present a knowledge base-assisted method to develop functional decomposition-models of an overall purpose function. First, an overall purpose function is decomposed into purpose sub functions, using a function-library in which existing functional decomposition design-knowledge is stored. This library archives descriptions of purpose functions that have "pointers" added to them, linking them to sub functions and to functions of which they are a functional element. An overall purpose function is decomposed into those sub functions to which it is linked in the library. Then, these purpose sub functions are mapped onto structures using a physical structure-library, in which descriptions of commonly used structures are archived. The purpose sub functions stored in the function-library also have pointers to the structures housed in the physical structure-library that are suitable to implement them, thus supporting function-structure mapping. These steps constitute the first stage of the DS-modeling framework. When functions from the function-library do not have pointers to physical structures as housed in the physical structure-library, hence cannot be mapped onto structures, a physical phenomena-library is then employed to carry out function-structure mapping. This library stores descriptions of commonly used physical behaviors and their effects, which have pointers added to them, linking them to structures in the physical structure-library. Action functions refer to behavioral effects (Deng, 2002). This physical phenomena-library is searched to retrieve those behavioral effects – action functions –- that are deemed suitable to achieve an unmapped purpose sub function. By linking a purpose sub function to a behavioral effect, which has a pointer added to a physical structure, purpose function-structure mapping is supported. These steps constitute the second stage.

The usage of these libraries in specifying models of functional decomposition (and supporting function-structure mapping) is aimed at employing past design knowledge in a systematic way to assist engineering designing (Deng, 2002). Models of functional decomposition are constructed that consist of sub functions for which structures are known. For instance, Deng et al. (2000a) specify a purpose sub function of the overall purpose function of a rivet setting device as "to exert certain force on the rivet by a working head, during the process the working head moves down a specified distance" (p. 43), which contains a pointer to the structures of "working head" and "rod". This type of designing in which known function-structure relations (and function-behavior-structure relations) are employed in constructing functional decomposition-models is also referred to as design-by-analogy or analogy-based-design (Goel & Bhatta, 2004).

Functional decomposition-model

Relative to the behavior, effect, and purpose meaning of technical functions, DS-purpose functions and sub functions can be taken to refer to states in the world desired by an agent-as-designer. For instance, the sub function above refers to the desired state that a rivet has force applied to it, come about by a sequence of states pertaining to the position of the working head. DS-models thus are purpose function-fm_D 's (Figure 5).

Relative to the five key concepts, the concepts of action and behavior are bypassed in the first stage and sub functions in DS-fm_D 's directly relate designer purposes to structures. (In the second stage, the concept of behavior is not bypassed and effect-functions are used to relate designer purposes to behavior. In this stage the step from goal to behavior is taken via a single function, not via a model of functional decomposition).

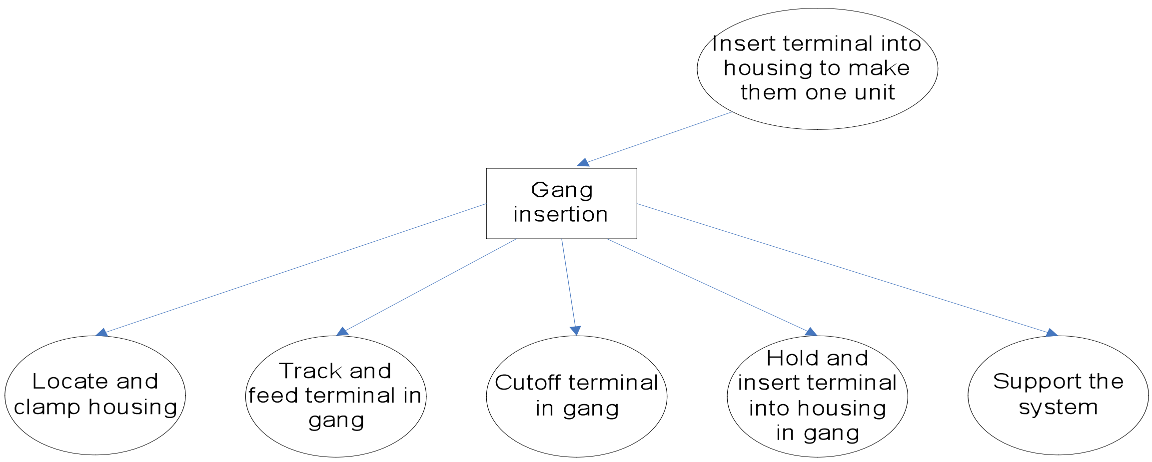

Figure 5 DS purpose function-fm_D of a terminal insertion device (part of an automatic assembly system for manufacturing electronic connectors, the block "gang insertion" refers to knowledge about physical structures that implement the functions, depicted in the oval nodes) (Deng, 2002)

3. Choosing functional decomposition-models: design knowledge employment and design objectives

Returning to the notion to discard a number of functional modeling approaches and settle for a single and common framework for functional modeling, here an alternative position is developed. I will argue that the choice for constructing particular models of functional decomposition (behavior function-fm_D 's, effect function-fm_D 's, or purpose function-fm_D 's) is based on their suitability for achieving particular design objectives. And that none of these three models alone is (best) suited for achieving the three considered objectives of innovative design, design analysis, and design-by-analogy. Given the suitability of particular models for particular objectives, one can both explain and defend the keeping of different models of functional decomposition side-by-side (and the approaches in which they are advanced) in engineering design.

Consider that, due to particular design objectives, particular design knowledge is or is not used in the construction of models of functional decomposition: construction of a model can be based on known function-structure connections for the functions in the model (DS), known behavior-structure relations that implement the functions in the model (FIL), or, instead, not based on such (types of) knowledge (FB). Precisely the type of design knowledge that is or is not employed, as due to design objectives, makes the models suitable for achieving the objectives for which they are advanced.

Consider FB-models that are used to support the objective of innovative design: relating goals to structures by fm_D 's without employing known function-structure connections or behavior-structure relations during construction of these fm_D 's. Since behavior and structure are not taken into account in the construction phase, behavior function-fm_D 's are suited for relating goals to structures since behavioral descriptions (which may include effects) are detailed enough to support the selection of structures after the model is constructed. Purpose function-fm_D 's and effect function-fm_D 's, instead, are too coarse-grained to allow the selection of structures in any precise way, when existing knowledge on behaviors and structures is not considered in the construction phase of such models. The use of such models, skipping reference to behaviors and effects in purpose function-fm_D 's and to behaviors in effect function-fm_D 's, does not give (in a precise manner) those structures that exercise certain behaviors, resulting in certain effects that are suitable to achieve the goals one wants realized. In the case of purpose function-fm_D 's, the designer may choose to select structures already known to him/her to achieve the purpose-functions in the model, but this changes the objective of innovative design into design-by-analogy (precisely the objective for which models of functional decomposition are employed in the DS approach). The use of effect function-fm_D 's to relate goals to structures, skipping reference to behaviors, also seem to provide insufficient precision for selecting (potentially innovative) structures that exercise behaviors which result in the effects desired (although more precision is gained than using purpose function-fm_D 's). For instance, a car's headlight effect-function "light on" may be sufficient to select well-known structures of an incandescent lamp or halogen one, but without a desired behavioral specification, the choice for, say, a more recent LED lamp (which differs in its behaviors by which the effect "light on" results) is not obvious (again the design objective would shift from innovation to analogy).

Now consider FIL-models that are used to support the objective of design analysis: relating goals (FIL-purposes) to behaviors (of structures) by fm_D 's that are constructed based on known (and required) behavior-structure relations of an existing design. Since behavior and structure are known, effect function-fm_D 's are suited for relating goals to behavior, since they allow verifying whether the behaviors exercised by structures display (in the intended fashion) the effects that are desired for contributing to the goals of the device. Using a purpose function-fm_D, instead, skipping reference to effects, does not give the precision to ascertain whether or not the desired effects are indeed manifested *in the intended way* by the behaviors of the device. For instance, the purpose function "illumination in a room" seems sufficient for determining whether the behavior of the device implements the effect-function “light on”. Yet, only an effect function-description, say “switch on-light on”, is suited for verifying whether the behavior of the device implements this effect in the intended way: say, the switch might be “off” while the light is still on. The device’s behavior, in this case, implements a desired effect but not in the intended fashion. This goes undetected with the purpose function-description “illumination in a room” (More elaborate behavior function-fm_D ‘s may also do the trick, but are unnecessarily complex in this setting).

Consider, finally, DS models that are used to support the objective of design-by-analogy: relating purposes to structures by fm_D ‘s that are constructed based on known (purpose) function-structure connections for the functions in the model. Since these connections are known, purpose function-fm_D ‘s are suited for directly relating purposes to structures. Constructing more elaborate behavior function-fm_D ‘s or effect function-fm_D ‘s is unnecessary for this objective, only adding additional complexity to the design task and decreasing efficiency (if, however, there are no structures available for the purpose functions, behavior function-fm_D ‘s or effect function-fm_D ‘s do become suited for relating purposes to structures. See, for instance, the use of effect-functions in the DS approach for relating purpose to behavior and then structure).

In sum, different models of functional decomposition are suited for different objectives (and as the “switch on-light on” example above shows, particular representational frameworks are suitable for particular objectives as well). Therefore, I submit that the co-existence of different approaches, advancing specific fm_D ‘s, has engineering value and is to be preferred above a single and common framework for functional modeling. A task remaining is then to relate different fm_D ‘s.

This step of relating different fm_D ‘s is developed in more detail in (Van Eck, 2010a,b). The idea behind it is that in order to relate behavior function-fm_D ‘s to effect function-fm_D ‘s or to purpose function-fm_D ‘s, the information expressed in the effect function-fm_D ‘s or purpose function-fm_D ‘s must be expanded in order to relate them to behavior function-fm_D ‘s. For instance, whereas an effect function-fm_D only represents desired outputs such as ‘producing torque’, a behavior function-fm_D contains more elaborate descriptions such as ‘conversions of electricity (input) into torque and heat (output)’. By expanding the desired effect (or purpose) descriptions with input and (other) effect descriptions (such as ‘electricity’ and ‘heat’), the descriptions become behavior-function descriptions that meet physical laws. Such descriptions are the ones advanced in behavior function-fm_D ‘s. By rephrasing effect-function (or purpose-function) descriptions as behavior-function descriptions by expanding them one can thus relate different fm_D ‘s. Vice versa, one can move from behavior function-fm_D ‘s to effect function-fm_D ‘s or purpose function-fm_D ‘s by selecting and describing only specific elements of behavior function-descriptions, namely their desired effects.

4. Concluding remarks

In this paper I have analyzed the use of different models of functional decomposition in engineering design. I considered models that refer to sets of desired behavior-functions, to sets of desired effect-functions, and ones that refer to sets of purpose-functions. It is shown that the choice for and suitability of particular models of functional decomposition depends on the design objectives for which these models are employed. Based on this result, it is concluded that the co-existence of different models has engineering value and is to be preferred above a single and common framework for functional modeling.

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