DEFINITION OF THE FORM-BASED DESIGN APPROACH AND DESCRIPTION OF IT USING THE FBS FRAMEWORK

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Abstract

The most of design methods and tools consider product functions as the basis to generate design solutions, but in the aesthetic and industrial design the situation is different. The sensorial experience during the interaction between users and products is the focus of the design process. It is composed by three elements: form, function and emotion; functions are only one of the elements. There is not a clear definition of this design approach, and no methods exist to describe its processes. The FBS framework allows describing design approaches based on user needs and functions, from which the technical requirements of the products are derived. It is not suitable as it is, but its flexible and generic structure makes it the candidate to become a descriptive method for the form-based design approach. The goal of this research is to define the form-based design approach and to describe it by exploiting the FBS framework. To achieve this, the form is introduced as a variable and the processes exploiting it are defined. Thanks to a comparison with the processes belonging to the FBS framework, this is modified and integrated to be able to describe the form-based design approach.

Keywords: Design process, Form-based design approach, Function-Behaviour-Structure Framework

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

Traditional design methods and tools are focused on the paradigm "form follows function". The product, its structure and external form or appearance are subordinated to the functions the product is called to make available. One of the theories stating the importance of functions comes from the Bauhaus school. Gropius, one of the founders, said "the Bauhaus is seeking - by systematic practical and theoretical research in the formal, technical and economic fields - to derive the design of an object from its natural functions and relationship". This has been restated by Mies van der Rohe, "every how (product structure) is carried by a what (function)" (Redstrom, 2006). In recent years, Gero and Kannengiesser (2004) developed the Function-Behaviour-Structure - FBS - framework; it allows focusing on the cognitive aspects of design activities by describing in detail all the variables and processes involved in design approaches having functions as the starting point.

Despite its wide use, this approach is scarcely followed in the industrial and aesthetic design where the main goal is to build products aimed at arousing particular sensorial experiences. A sensorial experience is defined as "the entire set of effects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning), and the feelings and emotions that are elicited (emotional experience)" (Hekkert, 2006). Three elements are fundamental for a good sensorial experience: the form for the aesthetic experience, the functions for the experience of meaning and the raised emotions for the emotional experience. These elements are equally important and must be considered together; any lack could spoil the success of the product. One example of this can be found in the Power Mac 4G Cube of Apple (2001). Apple developed a new computer aiming at arousing a strong emotional experience thanks to its shape, dimensions and performance; e.g., it used a fanless, convection-based cooling system that made it almost silent. Unfortunately, Apple chose to build the Cube without taking much care of the real needs of the final users; for this reason, the Cube did not allow a satisfactory experience of meaning (Edwards, 2010). For example, the Cube was a closed system; there was no way to customize it by adding PC cards, etc. Moreover, the CD/DVD slot was positioned on the top of the case instead of on the front, and this returned to be reputed as unnatural. Finally, such a high price for a product showing so many drawbacks was unjustified. All these aspects forced Apple to suspend the production after only one year because of the low sales. On the contrary, a different example where all the three elements of the sensorial experience are considered and quantified is offered by Alessi (2014), an Italian industry producing iconic objects, mainly home appliances. Alessi's design process starts from the analysis of forms, where the aesthetic experience is conveniently taken into account. Then, the most appropriate functions are assigned, looking at the real needs of the final users. This way, the experience of meaning is given the right importance as well. Finally, the product is built, aiming at arousing particular user feelings thanks to the synergy between form and functions, all of this referring to the emotional experience. The form-based design approach is spreading also in other fields. Mikkonen and Hsieh (2013) follow it to design flexible and deformable interfaces. Their approach is focused on the perceptions that designers feel by seeing and touching specific forms. These perceptions are then transformed into functions for real products that will implement at best the natural interaction with the users.

Unfortunately, form-based design approaches are not defined in a precise and univocal way. Moreover, there are not models to describe the variables and processes involved. To overcome these lacks, the experiences of Alessi and Mikkonen and Hsieh could be used as the starting point for defining this design approach. They appear as good candidates because their robust and well-developed processes consider all the three elements of the sensorial experience. Moreover, the FBS variables and processes could be used to describe this approach in detail, thanks to their generic and flexible architecture. Hence, the goals of this research are first to define the form-based design approach by exploiting the Alessi's and Mikkonen and Hsieh's work; secondly, to describe this approach using the FBS variables and processes. The resulting reference model will likely be useful in developing complete prescriptive frameworks for the aesthetic and industrial design.

The document starts with the descriptions of the Alessi's and Mikkonen and Hsieh's experiences and of the FBS framework. Then, the activities section focuses on the definition of the new variables and processes of the form-based design approach. Then, the description of this approach within the FBS framework takes place. Finally, the discussion and conclusions sections close the document.

2 BACKGROUND

2.1 Alessi’s design approach

Alessi (2014) considers the aesthetic and the emotional experience as key points; at the same time, functions and price are given great importance. Alessi's design approach starts from the analysis of forms generated by several famous architects and graphic and aesthetic designers. This analysis allows defining products implementing functions that arouse specific emotions in the users. Finally, products are evaluated to decide if all the initial requirements have been satisfied. Alessi's designers apply a formula to evaluate products and understand if these will be profitable. This formula contains four indices: the SMI - sensation, memory, and imagination - which tries to represent what people mean when they say "oh, what a beautiful object!", the CL - communication language - measuring the ability of a product to communicate something like status or values, the functions and the price. Every indices have a range of values of 1 to 5. The convenience in carrying on the development of a product comes from the sum of the four values assigned to the indices (Tischler, 2009). In the Alessi's approach, user needs are taken into account in the function index because functions are considered as the answers to the user needs. If the user does not understand how to use a product, this could be the most beautiful and fashionable ever, but it will be rejected. This happened for example with the Conico Water Tea Kettle designed by Aldo Rossi. This kettle had a particular and original form arousing several emotions, but that time Alessi did not fully consider the needs of the real users. The big problem was in its handle; it became too hot. The function "boil the water" cannot be performed completely because users could not use the handle without burning their hands. Alessi acknowledged the mistake and considered that failure as an important lesson (Wylie, 2001).

2.2 Mikkonen and Hsieh's design approach

The design and prototyping approach of Mikkonen and Hsieh aims at generating good sensorial experiences by considering specific forms (Mikkonen and Hsieh, 2013). Three elements are fundamental here: forms, use cases and the interaction between users and forms. The design process runs through several phases. At the beginning, the designers are introduced to the specific case study and the expected activities. The designers start to touch blindly some mock-ups and express their sensations. Then, the mock-ups are evaluated using the sight, without and with considering a given context where designers are called to empathize with the mock-ups. The designers can also ask to final users to perform the same activities to get more data about the sensorial experience. At the end of the evaluation, the designers express which behaviour and functions the specific forms inspired and those eventually disliked. The outcomes are considered to improve the mock-ups for the specific case study. Then, new prototypes are generated and compared with the previous ones to highlight possible improvements. When the prototype reaches a satisfactory level of maturity, it can be considered as an effective starting point for the development of the final product. This method underlines the importance of the form and of the context where the form is considered.

2.3 The situated Function-Behaviour-Structure framework with integration

The Function-Behaviour-Structure - FBS - framework (Gero, 1990) is a conceptual scheme that generalizes and organizes heterogeneous groups of entities and processes to begin and continue design activities. It is an ontology made by classes of variables and by their transformations during the activities of a generic design process. The FBS framework has been updated more times and this research considers the most recent release, the situated FBS framework (Gero and Kannengiesser, 2004) with the integration described in Cascini, Fantoni and Montagna (2012). This release includes important improvements as the definition of different environments (worlds) and the possibility to consider more actors (named agents). For the moment, only the designer is present as agent.

The situated FBS framework with integration describes any design activity through five variables and ten reference processes, which take place in three different environments. The variables are as follows.

- Function - F, which describes the aim of the product, i.e., what the product is for;
- Structure - S, which describes product components and their relationships, i.e., what the product is;
- Behaviour - B, which describes the attributes derived or expected from the structure of the product, i.e., what the product does;

- Need - N, which is expression of perceived desirable situations to be attained or undesirable situations to be avoided, explicitly stated by the designers or perceived thanks to observations of user behaviour;
- Requirement - R, which represents measurable properties of the product related to one or more needs.

The three environments where these variables are managed refer to the designers and their perceptive sphere. These environments are the external world - ^{e}, made of representations outside the designers; the interpreted world - ^{i}, constituted by sensorial experiences, concepts and interpreted representations of the world the designers interact with; and the expected world - e^i, the world where the effects of the designers' actions are imagined according to the goals and the interpretations of the current state of the external world.

The ten reference processes collect thirty sub-processes that the F, B, S, N and R variables undergo. The processes are as follows.

- Need identification. Here customer needs N^e are investigated and transformed into expected needs Ne^i, the goals to achieve.
- Requirement definition. It analyses and interprets the expected needs Ne^i to generate the requirements R^i, the basis for the generation of design solutions.
- Formulation. This process produces the interpreted representation of the F, B and S variables - F^i, B^i and S^i - starting from the list of the interpreted requirements; then, it focuses on the initial design state space constituted by their expected representations: Fe^i, Be^i and Se^i.
- Synthesis. It generates the external representation of the object structure S^e, starting from its expected behaviour Be^i.
- Analysis. It investigates the synthesized structure S^e to gather the interpreted behaviour B^i.
- Evaluation. It compares the interpreted behaviour B^i to the expected behaviour Be^i thanks to the analysis of the design solutions.
- Documentation. This process produces a design description, e.g. for manufacturing, after the achievement of a positive evaluation of the design solutions.
- Reformulations (types 1, 2 and 3). If the solutions should not fully solve the design problem, the reformulations reconsider sub-processes belonging to the previous seven processes to address corrections and improvements. The three different type of reformulations depends on the variable the solutions refer to: F, B or S respectively.

Just for brevity, from now on the situated FBS framework with integration will be addressed as FBS.

3 ACTIVITIES

The first step to define the form-based design approach is to determine the meaning of the term form. Once done, the processes of the design approach can be defined by exploiting Alessi's, as well as Mikkonen and Hsieh's work. It is important to underline that here forms are considered as already existent, generated in advance. This because the form generation requires particular aesthetic and psychological knowledge, quite unusual for designers and far from the classical design fields currently covered by the FBS. Then, the processes of the form-based design approach are compared with the FBS ones to highlight possible missing coverages and/or misalignments. This comparison leads the FBS update by introducing new variables and processes, in order to make the FBS able to describe this kind of design approach.

3.1 The form concept

The form concept cannot be defined univocally because of its dependence from the context. For example, in printmaking the form is the style, design, and arrangement in an artistic work as distinct from its content; in philosophy, the form is the essential nature of a species or thing, especially (in Plato’s thought) regarded as an abstract ideal which real things imitate or participate in (Oxford Dictionaries). In the design field, the form is the visible shape or configuration of something and the particular way in which something appears or exists (Macmillan Dictionary). Starting from these definitions, in this research the form describes the shell of the product or of a part of it; it is independent from the internal structure, the components and the material of the product. The form represents the affordance of the product. This refers to what and how well the product, with its form, colours, symbols, etc., suggests to do with it; it represents the potential and entangled relationship between the users and the products (Maier, Fadel and Battisto, 2009; Cormier, Olewnik and Lewis, 2014).

3.2 Processes of the form-based design approach

The introduction of the form concept allows the design approach based on it to be defined. Alessi's, Mikkonen and Hsieh's work helps in highlighting the six processes that compose it: form analysis (labelled as P1), highlighting and analysis of user needs (P2), prototype generation (P3), prototype exploitation (P4), documentation (P5) and revision (P6).

In the form analysis (P1), designers study specific forms selected for the product under development. As suggested by Mikkonen and Hsieh, these forms are studied and tested by the designers using the touch and the sight, separately. Then, designers express their feelings and perceptions sensed during the experiences in terms of affordance, behaviour and functions that the forms could suggest. At the same time, designers need to highlight and analyse the user needs (P2). Data are collected using interviews and/or anonymous questionnaires involving real users that will use the product. This is suggested by the Alessi's experience of the kettle failure, caused by some carelessness about user needs. In the generation of the prototype (P3), the user needs are compared with the designers' perceptions generated in P1, to establish if the semantics associated by designers to the specific forms could match one or more needs. If yes, forms are selected and a first prototype is generated, as suggested by both the Alessi's and the Mikkonen and Hsieh's approaches. P4 consists in the evaluation of this prototype, aimed at verifying if it satisfies the needs of the real users. This process is common to all the design methods to reduce time and costs of further redesign. The evaluation is focused on the functions and on the interaction allowed by the prototype. If the evaluation gives positive answers, P5 is performed, where the product specifications are defined and documented in detail. Otherwise, P6 takes place, where the prototype, functions, interactions and forms are revised in trying to answer to the user needs as best as possible. These activities are suggested by Mikkonen and Hsieh, where the participants can freely modify the forms during the design activities.

3.3 Exploiting the FBS

The exploitation of the FBS in describing the form-based design approach requires first to establish if the form is already considered by the existing FBS variables. Therefore, the form concept is compared with the FBS variables and it is quite clear that it cannot be represented by any of them. In fact, F (function) expresses the goal of a product, not its affordance. The same is for B (behaviour); it describes how the product interacts with the user, but it does not say anything about how the product inspires the user to use it. S (structure) is the only variable eligible, because of its apparent analogies with the form, given that both of them refer to tangible aspects of the product. Unfortunately, S describes real components, physical parts and assemblies of the product, while the form refers only to the external shell without taking care about the internal morphology, materials, and the relationships among the different product components. Moreover, form may refer to an idea, a concept, everything not necessarily real, because its goal is to achieve a particular affordance without the need to have something completely defined to evaluate.

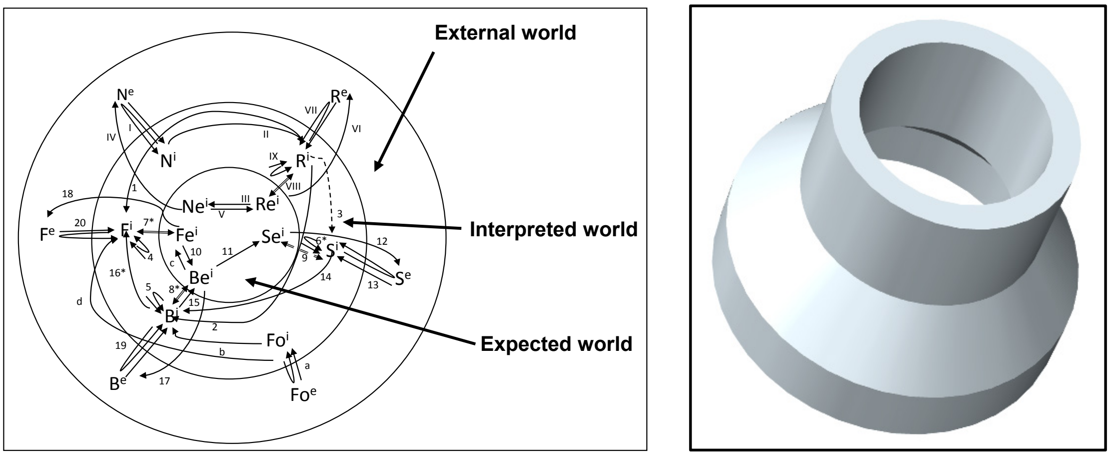

Figure 1. FBS model of the form-based design approach and form used in the example

Therefore, the form needs a new variable to be addressed. This variable will be named Fo, to distinguish it from the existing F.

Then, the six processes can be compared with the FBS ones, aiming at verifying the coverage, highlighting possible lacks and suggesting the related updates to be introduced. These updates are fairly expected, given that the product functions highlighted thanks to the analysis of user needs are replaced here by specific forms (Fo) decided in advance. The new sub-processes introduced in the following are labelled with lowercase letters in order to diversify them from existing sub-processes (represented by Arabic and Roman numerals) and variables (uppercase letters), and to be easily recognizable in figure 1, where the release of the FBS resulting from this research is shown. On the contrary, modified sub-processes maintain the original labels; an asterisk is added just to mean their update. For every new or modified sub-process, an example focused on the variables involved is proposed.

P1. Form analysis. P1 has to be introduced from scratch because in FBS there is nothing able to cover it. As recommended by Mikkonen and Hsieh, forms need to be analysed from the affordance point of view, perceived while testing them using touch and sight. This analysis allows the behaviour that the forms suggest to be interpreted (Thill et al., 2013). Then, starting from this, the product expected behaviour is defined. Finally, expected behaviour is transformed into expected functions. The expected behaviour and functions, together, represent the goals to achieve starting from the form. The description of all of this requires four sub-processes; three are new and one comes from the modification of an existing one. All of them are placed before the highlighting and analysis of user needs. These sub-processes are as follows.

- $Fo^e \rightleftarrows Fo^i$ (a). Designers start to analyse the given form (Fo^e) and interpret it (Fo^i) using sight and touch, separately. The interpreted form consists in its description in the designers' mind. For example, consider the form shown in fig. 1. In this case, its interpretation includes the through hole, the two outer cylindrical shapes in the upper and in the lower parts of the form and the conical link between them.
- $Fo^i \rightarrow B^i$ (b). Designers define the interpreted behaviour (B^i) that they deduce from the interpreted form (Fo^i). This task could be quite hard for unskilled designers; they risk to deduce functions rather behaviour, given the familiarity they have with the former rather than the latter. An easy way to avoid this problem is to base the analysis on the if-then statement. For example, an interpreted behaviour suggested by the form of figure 1 could be "if the form comes to be positioned vertically, rested on the larger cylindrical part, then it should remain in balance even if something hits it". Another interpreted behaviour could be "if the same form is laid down on the lateral side, then it should start to roll". All of this suggests going slightly deeper on how to discriminate between product behaviour and function. If the product reacts to something, this should be considered as behaviour; if the product makes something to happen, this should be addressed as a function.
- $B^i \leftrightarrow Be^i$ (8*). In this sub-process, the interpreted behaviour (B^i) is analysed to create the expected one (Be^i). This happens thanks to a translation into a generic definition, more focused on the design goals. This sub-process is already present in the FBS as the eighth sub-process of the formulation. It has the same goal but it must be used here too to select the behaviour worth to be

developed. In the example, the interpreted behaviour "if the form comes to be positioned vertically, etc." is translated into the expected one "a product replicating the form and positioned with the larger cylindrical part as base, achieves a good equilibrium". The other interpreted behaviour "if the form is laid down, etc." becomes "a product replicating the form and laid down on the lateral side undertakes a circular motion".

- $Be^i \leftrightarrow Fe^i$ (c). The expected behaviour (Be^i) is transformed into expected functions (Fe^i), those ones the product should implement to satisfy the users' expectations. In the example, the second expected behaviour is translated into the expected function "thanks to the circular motion achieved by laying down the form on the lateral side and thanks to the sharp edge, a product replicating this form could allow cutting paper and metal sheets roundly instead of linearly".

P2. Highlighting and analysis of user needs. This process can be put into relationship with the need identification and the requirement definition of the FBS. Their goal is to find the user needs to be used as the starting point for the generation of the design solutions. In the form-based design approach, the analysis aims at discovering the real needs of the users and at comparing them with the behaviour and functions identified in P1. The two goals are different, but both of them identify the user needs and analyse them to transform them into variables more suitable for achieving design solutions. Therefore, P2 can be considered as completely covered by existing FBS processes.

P3. Prototype generation. The goal of P3 is to generate a prototype of the product starting from the outcomes of P2; in other words, it aims at defining the external structure (S^e). The formulation and the synthesis in FBS already aim at this goal, but there are some differences. In the classic, function-based design approach, the interpreted function (F^i), behaviour (B^i) and structure (S^i) are generated starting from the interpreted requirements (R^i). Then, the expected values for all the three variables are generated (Fe^i, Be^i, Se^i). After that, the expected functions (Fe^i) are transformed into further expected behaviour (Be^i) and structure (Se^i). In the end, everything contribute to the definition of the external structure (S^e). This variable represents the structure of the prototype before the evaluation. Therefore, the results of the two approaches are the same. Nevertheless, this is not true for the sub-processes. Here the comparison aimed at selecting the best solutions deals with the function and behaviour variables only, because the structure does not come directly from the analysis of the form. This implies that the three FBS sub-processes of the formulation dealing with structure are not present in the description of the form-based design approach. They are the third sub-process, dealing with the transformation of the interpreted requirements into interpreted structure ($R^i \rightarrow S^i$), the sixth that creates the constructive memory starting from structure ($S^i \leftleftarrows$) and the ninth that transforms the interpreted structure into expected structure ($S^i \leftrightarrow Se^i$). On the contrary, the sub-processes of the synthesis hold true, because they define the translation from the theoretical goals (expected functions and behaviour) to the real structure/prototype aimed at obtain these goals.

P4. Prototype exploitation. Once the prototype has been generated, it is used to evaluate the users' satisfaction about the proposed design solutions. Since the structure has not been involved and analysed as deeply as it happens in the classic design approach, the evaluation of functions is coupled with the behaviour one and functions assume now a central role. The analysis and evaluation processes in FBS partially cover this process because they focus only on behaviour. In the analysis, the external structure (S^e) (prototype) is analysed and interpreted (S^i) by the designers. From that, the structure is transformed into interpreted behaviour (B^i). In the evaluation, this behaviour is compared with the expected one (Be^i) coming from the formulation process. All of this makes the part of the evaluation focused on behaviour fully covered. Anyway, the one focused on functions is completely missing. Therefore, some more sub-processes are required. Two of them are added to the analysis and one to the evaluation. They already exist in the FBS but they are used elsewhere, so they are updated - if required - and moved here.

- $S^i \leftleftarrows$ (6*). The interpretation of the prototype structure (S^i) allows the designers' constructive memory to be updated. This is already described by the sixth sub-process of the FBS formulation. The goal is the same and consists in enriching the designers' knowledge in order to make it available for future design activities. This sub-process is moved after the first sub-process of the prototype exploitation because it would have been impossible to perform in its original position. Looking back to the example, consider the interpreted structure "the product is composed by two cylindrical parts linked together. Their diameter and height could be varied". The constructive memory generated from it could be "changing the height of the cylindrical parts could allow making cuts with different radius without changing the cutting tool. For example, spiral cuts could be made without interruptions by dynamically changing the extension of a telescopic cutting tool".

- $B^i \rightarrow F^i$ (16*). The interpreted behaviour (B^i) is transformed into interpreted functions (F^i). This sub-process is already used as the third sub-process of the third FBS reformulation type. Here it has the same goal but it is placed as the fourth of the prototype exploitation because it constitutes the link between the evaluation based on behaviour and that one based on functions. Consider the interpreted behaviour "if a product replicating the form is placed on a paper or metal sheet, it cuts circular, spiral or generic curved shapes through circular movements". The interpreted function could be "thanks to circular movements of the cutting tool and its mutual movements with the sheet to cut, the product makes accurate and complex circular, spiral and curved cuts easily".
- $F^i \leftrightarrow Fe^i$ (7*). The interpreted functions (F^i) coming from the prototype exploitation are translated into expected ones (Fe^i) and compared with those coming from P3. This sub-process is already present as the seventh sub-process of the FBS formulation but the goal is slightly different. Here the goal is to verify the goodness of the prototype thanks to the comparison between the interpreted functions derived from the prototype and the expected functions coming from P3. In the classic FBS, the goal is the selection of the expected functions - derived from the analysis of the user needs - to be developed in the prototype. This sub-process is replicated as the sixth (and last) of the prototype exploitation. Consider the expected function "thanks to the circular motion achieved etc." together with the interpreted function "thanks to circular movements of the cutting tool and its mutual movements with the sheet to cut, the product makes accurate and complex circular, spiral and curved cuts easily". The comparison between the two functions shows that they describe the same way to cut through curved movements. Hence, this cutting way is validated as one of the functions performed by the product under design.

P5. Documentation. The goal of this process is the translation of the validated expected functions, behaviour and structures (Fe^i, Be^i, Se^i) into product specifications. In the FBS, the documentation is the transforms Fe^i, Be^i and Se^i into external function (F^e), behaviour (B^e) and structure (S^e), in other words, into technical specifications for the product under design. Therefore, the two processes have the same meaning and results, so the FBS completely covers P5.

P6. Revision. P6 aims at revising design solutions considered as unsatisfactory. In the FBS, when some differences are observed between the expected behaviour and functions and the design solutions, the three types of reformulation come to the stage, focused on the revision of structure, behaviour and function respectively.

The first FBS reformulation type applies here as-is, because it covers all the actions required to analyse the structure. Given that the form variable Fo does not directly influence the structure, the sub-processes already present are enough.

The second FBS reformulation type does not fully cover the revisions required by the form-based design approach because of the presence of the form. In fact, unlike before, the form directly influences behaviour, and this must kept into consideration. Therefore, the new sub-process (b) introduced in P1 has to be replicated here, placed as the seventh sub-process of the revision process.

- $Fo^i \rightarrow B^i$ (b). Considering the form shown in figure 1, a new interpreted behaviour coming from reapplying this sub-process could be "if the form is grasped, it could slip and fall due to its weight".

The last FBS reformulation type cannot be adopted as it is as well, because the form is still not considered. In this case, a new sub-process has to be added as the twelfth sub-process of the revision.

- $Fo^i \rightarrow F^i$ (d). The interpreted form (Fo^i) has to be translated into interpreted function (F^i). In this way, new functions can be directly added thanks to the analysis of the form. Considering always the same form as example, a new function could be "the form standing up by the side showing the smaller diameter can be used as a glass to drink".

The introduction of the form variable Fo and four new sub-processes, together with the update/replace of four existing ones, make the FBS able to describe the form-based design approach. Table 1 compares the two releases of the FBS, the previous one - labelled as FBS(F) - and the newer - FBS(Fo). The changes will be discussed in the next paragraph.

4 RESULTS AND DISCUSSION

As a result of this research, the form-based design approach is now defined and described thanks to the FBS. The differences with the classic function-based approach, expressed in terms of variables, processes and sub-processes, are summarized in table 1. The first, main difference consists in the starting point: from one side there are the user needs transformed into functions and on the other, there are the forms. Then, the introduction of the form required changing several FBS processes and the addition of a new one, the form analysis. Moreover, the form analysis allows adding new information to the knowledge base derived from the sensorial experience not considered before and this enriches the generation of the design solutions. Anyway, what is equally interesting regards the processes that did not experience changes. The need identification, the requirement definition, the synthesis, the documentation and the first type of reformulation preserve their original structure and meaning. More than half of the FBS processes remain the same and this goes for the most of the sub-processes in the other processes. All of this means that the form-based approach does not completely subvert the traditional one; only some parts change, without disorienting the designers that can carry on using design methods and tools belonging to a design approach they are already familiar with.

Once summarized the positive aspects of the definition of the form-based design approach and its description thanks to the FBS, some drawbacks have to be mentioned. First, the large number of variables could make the reader puzzled; unfortunately, this cannot be changed because the FBS analyses the processes at a deep level and the number of variables is naturally high. For the moment, the goodness of the definition as well as the one of the description through the FBS cannot be fully verified, given that a comparison with processes coming from other descriptive models is missing. Moreover, nothing assures that the design solutions suggested by the forms satisfy the user needs. Although the reformulation processes are involved, forms could not suggest solutions for the design problem because they are somehow too "far" from the real needs of the users. Moreover, the technological feasibility is keeping to be ignored also in the form-based design approach, because forms do not contain information about the materials or technology involved. All these drawbacks have to be taken into consideration in a next release of the definition of the form-based design approach.

Table 1. Function-based vs. form-based design approaches as described by the FBS

FBS(F)		FBS(Fo)	
Process	Sub-processes	Sub-processes	Process
-	-	$Fo^e \rightleftarrows Fo^i$ (a), $Fo^i \rightarrow B^i$ (b), $B^i \leftrightarrow Be^i$ (8*), $Be^i \leftrightarrow Fe^i$ (c)	P1 Form analysis
Need identification	$N^e \rightleftarrows N^i$ (I), $N^i \rightarrow R^i$ (II), $Re^i \rightarrow Ne^i$ (III), $Ne^i \rightarrow N^e$ (IV)		P2 Highlighting and analysis of user needs
Requirement definition	$Ne^i \rightarrow Re^i$ (V), $Re^i \rightarrow R^e$ (VI), $R^e \rightleftarrows R^i$ (VII), $R^i \leftrightarrow Re^i$ (VIII), $R^i \leftrightarrows$ (IX)		
Formulation	$R^i \rightarrow F^i$ (1), $R^i \rightarrow B^i$ (2)		P3 Prototype generation
	$R^i \rightarrow S^i$ (3)	-	
	$F^i \leftrightarrows$ (4), $B^i \leftrightarrows$ (5)		
	$S^i \leftrightarrows$ (6)	-	
	$F^i \leftrightarrow Fe^i$ (7), $B^i \leftrightarrow Be^i$ (8)		
	$S^i \leftrightarrow Se^i$ (9)	-	
	$Fe^i \rightarrow Be^i$ (10)		
Synthesis	$Be^i \rightarrow Se^i$ (11), $Se^i \rightarrow S^e$ (12)		
Analysis	$S^e \rightleftarrows S^i$ (13)		P4 Prototype exploitation
	-	$S^i \leftrightarrows$ (6*)	
	$S^i \rightarrow B^i$ (14)		
	-	$B^i \rightarrow F^i$ (16*)	
Evaluation	$B^i \leftrightarrow Be^i$ (15)		
	-	$F^i \leftrightarrow Fe^i$ (7*)	

Documentation	$Fe^i \rightarrow F^e$ (17), $Be^i \rightarrow B^e$ (18), $Se^i \rightarrow S^e$ (12)		P5 Documentation
Reformulation (1)	$Se^i \leftrightarrow S^i$ (9), $S^e \rightarrow S^i$ (13), $S^i \leftleftarrows$ (6)		P6 Revision
Reformulation (2)	$Be^i \leftrightarrow B^i$ (8), $B^e \rightarrow B^i$ (19), $S^i \rightarrow B^i$ (14)		
	-	$Fo^i \rightarrow B^i$ (b)	
	$B^i \leftleftarrows$ (5)		
Reformulation (3)	$Fe^i \leftrightarrow F^i$ (7), $F^e \rightarrow F^i$ (20), $B^i \rightarrow F^i$ (16)		
	-	$Fo^i \rightarrow F^i$ (d)	
	$F^i \leftleftarrows$ (4)		

5 CONCLUSIONS

The paradigm "form follows function" is the base of the traditional design approach, where functions represent the starting point for the generation of design solutions. The FBS - Function-Behaviour-Structure - framework is a descriptive model that expresses at best the design approach based on this paradigm. Nevertheless, in the industrial and aesthetic design the paradigm is inverted, because they are more focused on the sensorial experience of users interacting with products. Now the form becomes the centre of the design process. Unfortunately, a descriptive model representing this approach is missing. The goals of this research were to define the processes of the form-based design approach and to describe them using the FBS variables and processes, in order to become a reference for the definition of future aesthetic and industrial design frameworks. This happened thanks to the introduction of a new variable, the form, and the addition of a new process and several changes in the other processes of the FBS.

The research would need some future developments. First, a complete and robust validation of the definition and description of the form-based design approach is required. From one hand, a validation of the definition in the field through some complete case studies will allow both a better understanding of all the processes and variables involved, and the quantification of the effectiveness of the new processes. On the other hand, a validation of the approach definition and the processes description through a comparison with other descriptive or prescriptive models could add new activities not present in the approaches analysed here or reduce the complexity of the description. Another important issue regards the activities performed to generate the forms. They are not considered now; forms are thought about as already existent. The analysis of all of this would help in understanding how designers associate an emotion to a specific form and how they generate the specific affordance that arouse that emotion in the user mind. Finally, users should have an active role in the processes of the form-based design approach, as suggested by Mikkonen and Hsieh. Now users are considered passive because they cannot intervene directly in the design process. They should have the possibility to give hints about the affordance suggested by the form, as well as to express their opinions during the evaluation process.

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ACKNOWLEDGEMENTS

The authors would like to thank prof. John Gero and prof. Gaetano Cascini for their valuable help in allowing us understanding the architecture and functioning of the situated FBS framework with integration.