The situated function–behaviour–structure framework

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This paper extends the function–behaviour–structure (FBS) framework, which proposed eight fundamental processes involved in designing. That framework did not explicitly account for the dynamic character of the context in which designing takes place, described by the notion of situatedness. This paper describes this concept as a recursive interrelationship between different environments, which, together with a model of constructive memory, provides the foundation of a situated FBS framework. The eight fundamental processes are then reconstructed within this new framework to represent designing in a dynamic world.

Keywords: design model(s), design process(es), design science, design theory, logic of design

Recent AI in design research has increasingly focussed on developing agent-based design systems (e.g. Campbell et al.[1], Grecu and Brown[2], Gero and Brazier[3]). Yet, many of these approaches have shown only limited success in supporting conceptual designing since they ignore one of conceptual designing's (as opposed to routine designing's) most distinguishing features. As not all the requirements are known at the outset of a design task, conceptual designing involves finding what is needed and modifying it again during the process. This makes the environment within which processes operate dynamic.

Many agent-based systems are based on traditional models and theories of designing that assume the world as being fixed, well-defined and unchanged by what you do. This static view of the world is not in accord with the results of empirical design research.[4,5] In order to develop computational design agents as aids to human designers, we need a model of designing in which all the knowledge is not encoded a priori and which allows for a changing world within which the agent operates.

1 Campbell, M I, Cagan, J and Kotovsky, K 'A-Design: theory and implementation of an adaptive, agent-based method of conceptual design' in **J S Gero and F Sudweeks** (eds) *Artificial intelligence in design'98*, Kluwer, Dordrecht (1998) pp 579–598
2 Grecu, D L and Brown, D C 'Expectation formation in multi-agent design systems' in **J S Gero** (ed.) *Artificial intelligence in design'00*, Kluwer, Dordrecht (2000) pp 651–671
3 Gero, J S and Brazier, F M T (eds) *Agents in Design 2002* Key Centre of Design Computing and Cognition, University of Sydney, Australia (2002)
4 Schön, D and Wiggins, G 'Kinds of seeing and their functions in designing' *Design Studies* Vol 13 No 2 (1992) 135–156
5 Suwa, M, Gero, J S and Purcell, T 'Unexpected discoveries and s-inventions of design requirements: a key to creative designs' in **J S Gero and M L Maher** (eds) *Computational models of creative design IV*, Key Centre of Design Computing and Cognition, University of Sydney, Sydney, Australia (1999) pp 297–320

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One formal representation of the processes of designing is Gero's[6] function–behaviour–structure (FBS) framework. Since its publication, some important insights have been gained from empirical design research, applying ideas from cognitive science. These can be summarized by the notion of situatedness, which emphasizes that the agent's view of a world changes depending on what the agent does. The FBS framework does not account for this concept and is therefore unable explicitly to make the move away from encoded knowledge.

The aim of this paper is to develop a situated FBS framework, in which the knowledge of the design agent is grounded in its experience and its interactions with the environment. We present a model of an open, dynamic world consisting of multiple interacting environments.

1 The FBS framework

The basis for Gero's[6] FBS framework is formed by three classes of variables describing different aspects of a design object:

- Function (F) variables: describe the teleology of the object, i.e. what it is for.
- Behaviour (B) variables: describe the attributes that are derived or expected to be derived from the structure (S) variables of the object, i.e. what it does.
- Structure (S) variables: describe the components of the object and their relationships, i.e. what it is.

A designer constructs connections between the function, behaviour and structure of a design object through experience. Specifically, the designer ascribes function to behaviour and derives behaviour from structure. A direct connection between function and structure, however, is not established.

The FBS framework represents designing by a set of processes linking function, behaviour and structure together, which can now be seen as different states of the developing design, Figure 1.

The eight processes depicted in the FBS framework are claimed to be fundamental for all designing. They are briefly outlined below:

- *Formulation* (process 1) transforms the design requirements, expressed in function (F), into behaviour (Be) that is expected to enable this function.
- *Synthesis* (process 2) transforms the expected behaviour (Be) into a solution structure (S) that is intended to exhibit this desired behaviour.

6 **Gero, J S** 'Design prototypes: a knowledge representation schema for design' *AI Magazine* Vol 11 No 4 (1990) 26–36

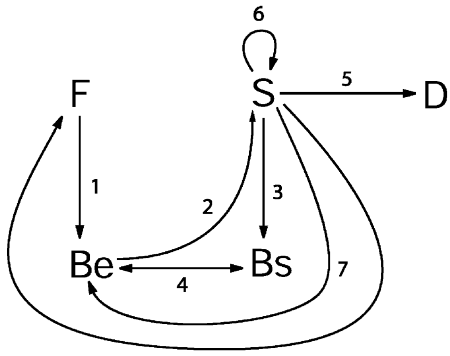

Figure 1 The FBS framework (after [6])

- *Analysis* (process 3) derives the 'actual' behaviour (Bs) from the synthesized structure (S).
- *Evaluation* (process 4) compares the behaviour derived from structure (Bs) with the expected behaviour to prepare the decision if the design solution is to be accepted.
- *Documentation* (process 5) produces the design description (D) for constructing or manufacturing the product.
- *Reformulation type 1* (process 6) addresses changes in the design state space in terms of structure variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.
- *Reformulation type 2* (process 7) addresses changes in the design state space in terms of behaviour variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.
- *Reformulation type 3* (process 8) addresses changes in the design state space in terms of function variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.

The most remarkable kinds of processes (in that they do not appear in most traditional models of designing) are those representing the reformulation of the design state space (processes 6–8). The most explored process of them is reformulation type 1; common examples are case-based reasoning[7] and structure analogy[8]. Empirical design studies confirm that the reformulation of structure is the predominant type of reformulation.[9] The same studies also reveal that the activity of reformulating the problem, in terms of expected behaviour or even function, diminishes during the design process, but never disappears.

The lack of these processes in most other approaches indicates the presence

7 **Maher, M L, Balachandran, M B and Zhang, D M** *Case-based reasoning in design* Lawrence Erlbaum, Hillsdale, NJ (1995)
8 **Qian, L and Gero, J S** 'Function–behaviour–structure paths and their role in analogy-based design' *AIEDAM* Vol 10 (1996) 289–312
9 **McNeill, T, Gero, J S and Warren, J** 'Understanding conceptual electronic design using protocol analysis' *Research in Engineering Design* Vol 10 (1998) 129–140

of a fundamentally different view of designing in the FBS framework. All three types of reformulation suggest a non-static world of designing, as they obviously give the on-going design process a new direction that was not anticipated before. However, in its current state, the FBS framework cannot show this open world explicitly.

2 Situatedness and constructive memory

Designing is an activity during which the designers perform actions in order to change the environment. By observing and interpreting the results of their actions, they then decide on new actions to be executed on the environment. This means that the designer's concepts may change according to what they are 'seeing', which itself is a function of what they have done. We may speak of a recursive process, an 'interaction of making and seeing'.[4] This interaction between the designer and the environment strongly determines the course of designing. This idea is called *situatedness*, whose foundational concepts go back to the work of Dewey[10] and Bartlett[11]. In paraphrasing Clancey[12], we can summarize it as 'where you are when you do what you do matters'.

In experimental studies of designers, some phenomena related to the use of sketches, which support this idea, have been reported. Schön and Wiggins[4] found that designers use their sketches not only as an external memory, but also as a means to reinterpret what they have drawn, thus leading the design in a new direction. Suwa et al.[5] noted, in studying designers, a correlation of unexpected discoveries in sketches with the invention of new issues or requirements during the design process. They concluded that 'sketches serve as a physical setting in which design thoughts are constructed on the fly in a situated way'.

An important idea, which fits into the notion of situatedness, has been proposed by Dewey in 1896[10] and is today called constructive memory. The main idea of constructive memory is that memory, instead of being laid down and fixed at the time of the original experience, must be newly constructed every time there needs to be a memory. Certainly, the original experience, which is to be recalled, is used to construct the memory of it. But this process is also governed by the situation pertaining at the time of the demand for this memory. Therefore, everything that has happened since the original experience determines the result of memory construction. Each memory, after being constructed, is added to the experience and thus becomes part of the situation, which affects the kinds of further memories that can be constructed.

Memory, as an overall term, must be seen as a process rather than a fixed

10 Dewey, J 'The reflex arc concept in psychology' *Psychological Review* Vol 3 (1896) 357–370(reprinted in 1981)
11 Bartlett, F C *Remembering: a study in experimental and social psychology* Cambridge University Press, Cambridge (1932)(reprinted in 1977)
12 Clancey, W J *Situated cognition* University Press, Cambridge (1997)

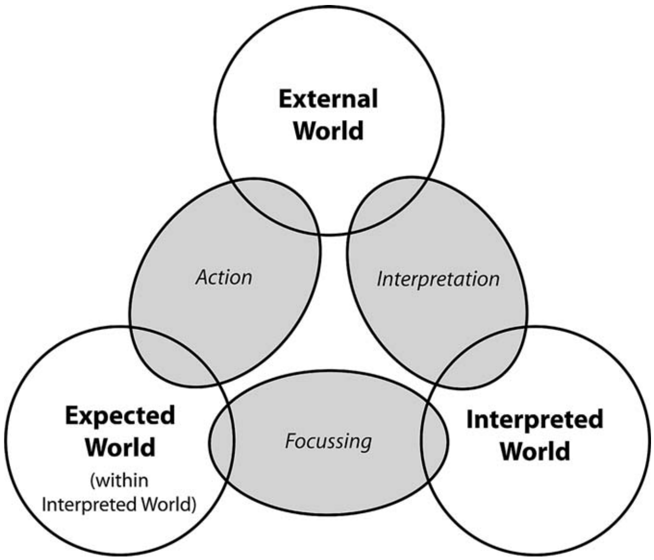

Figure 2 Situatedness as the interaction of three worlds

state. This idea has been exemplified by a quote from Dewey via Clancey: 'Sequences of acts are composed such that subsequent experiences categorize and hence give meaning to what was experienced before'. The significance of the idea of constructive memory in designing has been shown by Gero[13]. Situatedness and constructive memory thus provide the conceptual bases for grounding the knowledge of an agent in the situation being constructed by its interactions with the environment.

3 Creating a dynamic context for designing

We intend to develop a setting for representing designing in an open, dynamic context. The ideas of situatedness and constructive memory, founded on the constructive character of human cognition and grounding it in processes of interaction, provide a suitable conceptual basis for this endeavour. However, these ideas have to be developed further as well as modelled in more formal ways.

3.1 Modelling situatedness

We will approach situatedness by introducing three different kinds of environments that interact with one another, Figure 2.

The *external world* is the world that is composed of representations outside the designer or design agent.

The *interpreted world* is the world that is built up inside the designer or design agent in terms of sensory experiences, percepts and concepts. It is

13 **Gero, J S** 'Constructive memory in design thinking' in **G Goldschmidt and W Porter** (eds) *Design thinking research symposium: design representation*, MIT, Cambridge, MA (1999) pp 29–35

the internal, interpreted representation of that part of the external world that the designer interacts with.

The *expected world* is the world that the imagined actions of the designer or design agent will produce. It is the environment in which the effects of actions are predicted according to current goals and interpretations of the current state of the world.

These three worlds are recursively linked together by three classes of processes. The process of *interpretation* transforms variables, which are sensed in the external world into the interpretations of sensory experiences, percepts and concepts that compose the interpreted world. This is done by the interaction of sensation, perception and conception processes.[14] The process of *focussing* focuses on some aspects of the interpreted world, uses them as goals in the expected world and suggests actions, which, if executed in the external world should produce states that reach the goals. The result of *action* is an effect, which brings about a change in the external world according to the goals in the expected world.

We have depicted the expected world separately from the interpreted world to be able to explicitly delineate some important concepts and processes. However, it is important to note that the expected world is located within the interpreted world.

The different environments, connected to one another, form the *situation*, which thus consists of both the external world and the designer's internal world (note 1). The dynamics of the situation stem from the interaction of these three kinds of environments. Potentially, every change in one of the worlds brings about and is brought about by changes in the other world.

3.2 Modelling constructive memory

We will now develop the internal world itself in more detail. Here, we are dealing with the agent's knowledge that has been constructed and processed from former interactions with the external world. The notion of constructive memory captures this idea; however, it still needs more examination to be formally introduced into this framework of designing.

Constructing a memory has been described as being governed both by what was initially there (the original experience) and by what the current situation (made up of previous experiences and memories and the currently focussed concepts) makes with it. At this level of abstraction, constructive memory can be viewed in a similar way as the process of interpretation, which Gero and Fujii[14] have described as consisting of two parallel pro-

14 Gero, J S and Fujii, H 'A computational framework for concept formation for a situated design agent' *Knowledge-Based Systems* Vol 13 No 6 (2000) 361–368 cesses interacting with each other: a *push process* (or data-driven process), where the production of an internal representation is driven ('pushed') by the sensed data, and a *pull process* (or expectation-driven process), where the interpretation is driven ('pulled') by some of the agent's current concepts, which has the effect that the original data are biased to match the current expectations (about what the interpretation should be).

In this respect, we can use the idea of a push–pull process for generally representing the interaction of an agent with both its external environment (by interpretation) and its internal environment (by constructive memory). Figure 3 depicts how an original experience (E_0) is produced by interpreting something in the external world at a certain point of time. A push–pull process represents this transition from the external world to the interpreted world. The construction of a memory (M_1) of the original experience, at a later point of time, is also carried out by a push–pull process, but within the interpreted world. The pull process here is controlled by the current situation.

Figure 3 shows not only that the processes of interpretation and constructive memory can be represented in the same manner, but also that the result of one can influence the result of the other. Interactions of the interpreted world with the external world can have an impact on the construction of memories, and interactions of the interpreted world with itself can affect the construction (interpretation) of concepts.

The interpreted world, as depicted in Figure 3, thus 'wires itself up' through intertwined horizontal and vertical push–pull processes. Exploring these processes is out of scope of this paper. However, we now have a sufficient description of constructive memory for integrating it into a

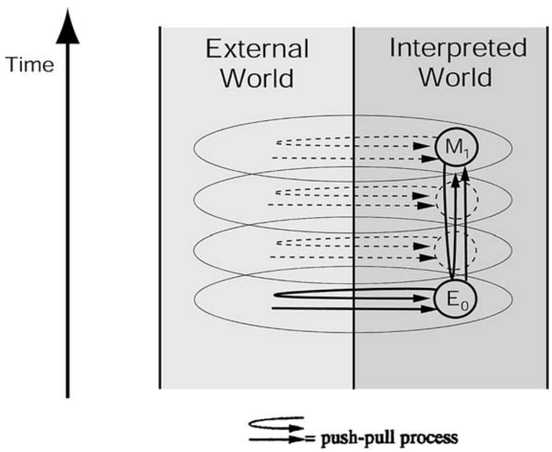

Figure 3 Interpretation and constructive memory

framework of designing. It contributes to our conception of an open multiple-world environment by providing an additional dynamic component inside the agent.

4 *The processes of designing in a situated perspective*

Having described situatedness and constructive memory, we are now able to develop a situated framework of designing. Our conception of a dynamic environment as three interacting worlds provides an initial setting, into which we can put the eight fundamental processes in designing. Figure 4 shows these worlds again, similar to Figure 2, however, nesting them to imply the design agent (as the internal world) is located within the external world. It also represents more explicitly that the expected world is a subset of the interpreted world.

Figure 4 also shows those general classes of processes that have been developed and described in Section 3. A push–pull process represents the interaction of the interpreted world and the external world (via interpretation) as well as the interpreted world interacting with itself (via constructive memory). The process of focussing connects the interpreted world and the expected world and is represented by a double-headed arrow. This accounts for the bi-directional character of this process, which ensures that some concepts may be focussed (and thus transferred into the expected world), whereas other concepts, which have been previously focussed, may be dropped (and thus transferred out of the expected world). The process of action is depicted as a transformation of an expected concept into an external representation.

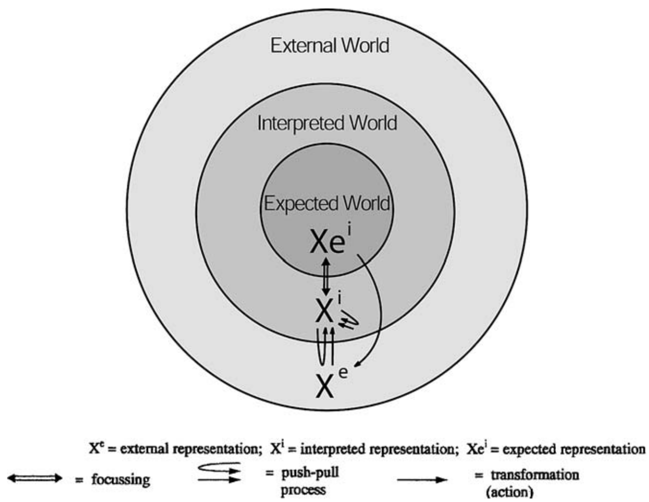

Figure 4 A dynamic setting for the design process

We will now develop a situated FBS framework using the foundations provided in Figure 4. This requires specializing each of the general concepts of external, interpreted and expected representations (X^e, X^i and X_e^i) with respect to the three classes of variables F, B and S.

The following step-by-step reconstruction of each of Gero's[6] eight fundamental processes in designing from our new situated perspective will illustrate how these processes have been developed as a consequence of distinguishing between representations in different worlds. To illustrate the processes in the situated FBS framework, we use the example of a window design.[15] Specifically, we use the following set of F, B and S variables to specify a window:

- F variables: 'enhancing winter solar gain', 'controlling noise', 'providing view' and 'providing daylight'
- B variables: 'thermal conduction', 'light transmission', 'direct solar gain'
- S variables: 'glazing length', 'glazing height', 'type of coating', 'glazing thickness', 'type of glass'.

4.1 Formulation

Formulation is an important process in conceptual designing, as it specifies an initial design state space, within which the design solution is searched. The original FBS framework does not provide a representation for the notion of a design state space; however, the expected world in our new setting can do exactly that. This gives us the possibility of showing the set of processes that produces a complete design state space in terms of F, B and S. To better exploit this capability, we explicitly depict the requirements (R) of a design problem.

The original FBS framework, due to the lack of a representation for the design state space (which is a consequence of the lack of the differentiation between different worlds), is restricted to the reasoning process from function (F) to expected behaviour (Be), Figure 5(a). In a situated environment, Figure 5(b), this activity is only one part of the process of formulation. First, the design agent interprets the explicit requirements (R) by producing the interpreted representations F^i and, eventually, B^i and S^i (processes 1–3), which are then augmented by representations (implicit requirements) originating from the agent's own experience (processes 4–6). An initial design state space is set up by focussing on subsets on these internalized (explicit and implicit) requirements (processes 7–9). Process 10 corresponds to the transformation of F into Be in the original FBS framework.

Example:

15 **Gero, J S, Tham, K W and Lee, H S** 'Behaviour: a link between function and structure in design' in **D C Brown, M B Waldron and H Yoshikawa** (eds) *Intelligent computer aided design*, North-Holland, Amsterdam (1992) pp 193–225

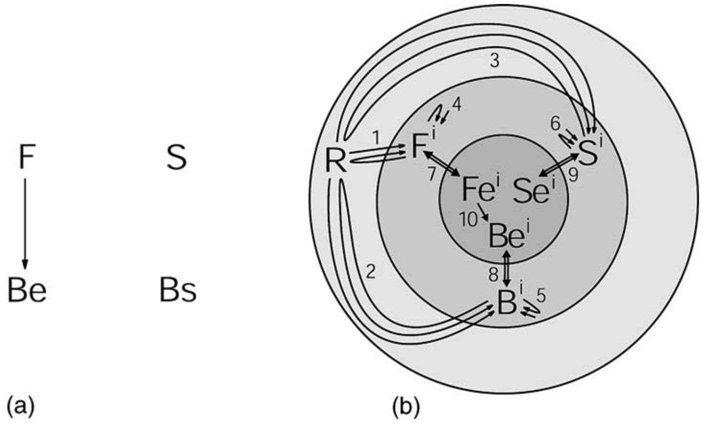

Figure 5 Formulation: (a) original, (b) situated FBS framework

–Process 1: uses R to produce F^i variables such as ‘enhancing winter solar gain’ or ‘controlling noise’.
–Process 2: uses R to produce B^i variables such as ‘thermal conduction’ and constraints on them.
–Process 3: uses R to produce S^i variables such as ‘glazing length’ and ‘glazing height’ and constraints on them.

The interpretation processes 1–3 are represented using the push–pull idea. This accounts for the common observation that different designers interpret the same requirements differently, such as viewing them as either ‘hard’ or ‘soft’. This classification depends primarily on the individual experience and interpretation of particular circumstances (e.g. the expected re-negotiability of some requirements). The categorization of the requirements into function, behaviour or structure can be stated explicitly in R or can result from the designer’s domain knowledge.

–Process 4: uses constructive memory to produce further F^i variables such as ‘providing view’ or ‘providing daylight’. These F^i variables result from the history of all F^i variables that have been constructed in current and previous design experiences.
–Process 5: uses constructive memory to produce further B^i variables such as ‘light transmission’. These B^i variables result from the history of all B^i variables that have been constructed in current and previous design experiences.
–Process 6: uses constructive memory to produce further S^i variables such as ‘type of coating’. These S^i variables result from the history of all S^i variables that have been constructed in current and previous design experiences.

The constructive memory processes 4–6 account for the fact that the set of externally specified requirements is never sufficiently complete in itself to commence designing. These processes produce implicit requirements that are either implicated as part of the 'common knowledge' in the domain (e.g. the functions of 'providing view' and 'providing daylight'), or they are produced as a result of the expertise of the individual designer (e.g. the behaviour variable 'light transmission' or the structure variable 'type of coating'). In both cases, they are subject to the experience of the individual designer.

–Process 7: focuses on a subset ($Fe^{i} \subseteq F^{i}$) of F^{i} to produce an initial function state space.
–Process 8: focuses on a subset ($Be^{i} \subseteq B^{i}$) of B^{i} to produce an initial behaviour state space.
–Process 9: focuses on a subset ($Se^{i} \subseteq S^{i}$) of S^{i} to produce an initial structure state space.
–Process 10: transforms Fe^{i} (e.g. 'enhancing winter solar gain') into Be^{i} (here 'direct solar gain').

4.2 Synthesis

Synthesis is the process of transforming expected behaviour into external structure. Figure 6(b) depicts this with two processes, one producing an expected structure (process 11), and one externalizing it, e.g. by sketching or some similar process (process 12). The original FBS framework did not distinguish between expected and external structure and therefore could only show the general process from Be to an unspecified S, Figure 6(a).

Example:

–Process 11: transforms Be^{i} (e.g. 'direct solar gain') into Se^{i} (here (ranges

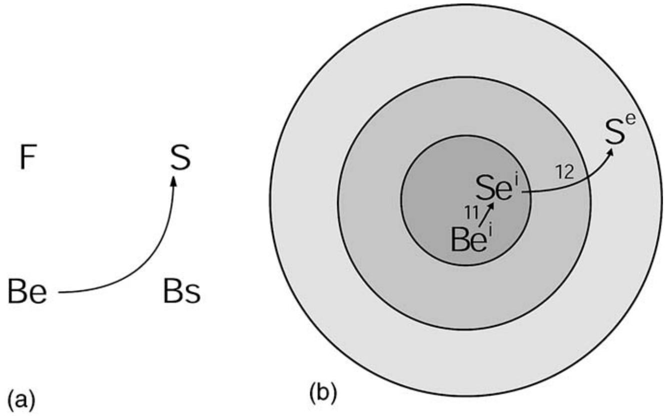

Figure 6 Synthesis: (a) original, (b) situated FBS framework

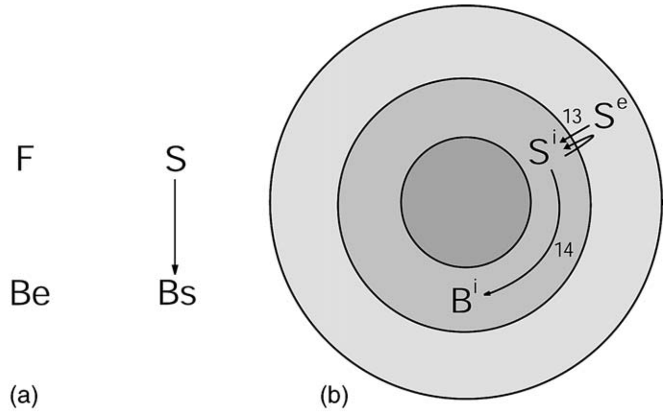

Figure 7 Analysis: (a) original, (b) situated FBS framework

of) values for the variables 'glazing length', 'glazing height', 'glazing thickness', 'type of coating' and 'type of glass').
–Process 12: transforms Se^i into S^e, for example, by producing an iconic representation of a rectangular window and/or symbolic representations of structure variables.

4.3 Analysis

Analysis, the derivation of behaviour from a synthesized (and thus external) structure, is represented by the two partial processes in Figure 7(b): the construction of an interpreted structure through interpretation (process 13) and its subsequent transformation into interpreted behaviour (process 14). Only the latter is explicitly represented in Figure 7(a), without the interpretation stage of the analysis process.

Example:

–Process 13: uses S^e as well as the current analysis goals to produce S^i. For example, a thermal analysis 'pulls' different S^i variables (e.g. the properties of the window glazing) than a structural analysis does (e.g. the properties of the window frame). Different representations of S^e can also 'push' this process to emerge S^i variables that have not been looked for initially.[16]
–Process 14: transforms S^i into B^i. For example, a thermal analysis transforms glazing properties into thermal conduction properties, while a structural analysis transforms frame properties into properties related to the resistance to certain loads.

4.4 Evaluation

The original FBS framework already distinguished between expected behaviour Be and behaviour derived from structure Bs (which corresponds,

16 **Gero, J S** 'Creativity, emergence and evolution in design' *Knowledge-Based Systems* Vol 9 (1996) 435–448

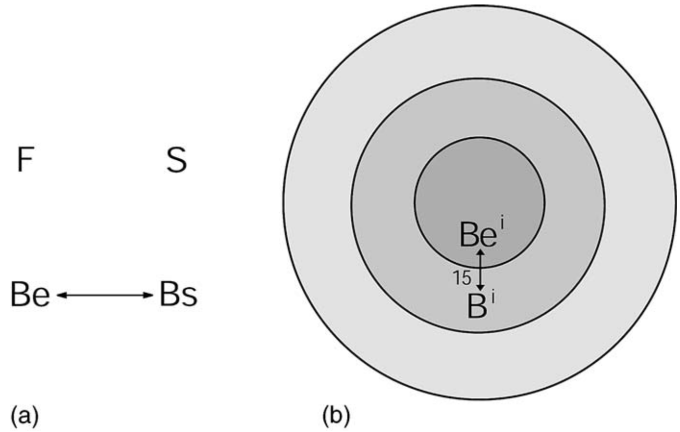

Figure 8 Evaluation: (a) original, (b) situated FBS framework

in this particular case, to interpreted behaviour B^i). Therefore, the evaluation process, which compares these two concepts, remains unchanged in our situated FBS framework, Figure 8(a) and (b).

Example:

–Process 15: compares the interpreted and the expected value of a particular behaviour variable, e.g. 'thermal conduction' and produces a result in terms of meeting the expected behaviour.

4.5 Documentation

This process denotes the production of the (external) description of a design solution. The original FBS framework described this process as the transformation of S into D, Figure 9(a). In the situated view, Figure 9(b), we generalize the design description as the (standardized) external representation of expected structure (process 12) and, if they need to be rep-

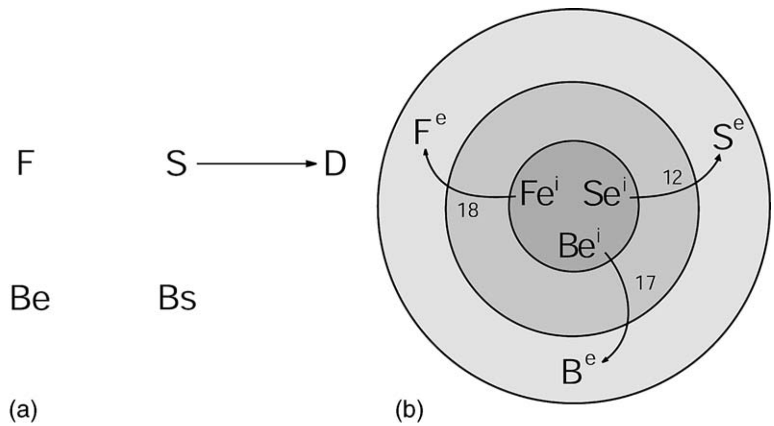

Figure 9 Documentation: (a) original, (b) situated FBS framework

resented, expected behaviour (process 17) and expected function (process 18).

Example:

–Process 12: transforms Se^i into S^e to be used as a design description for construction or manufacture. Today, the most common design descriptions include CAD drawings and component lists.
–Process 17: transforms Be^i into B^e to be added in the design description produced by process 12.
–Process 18: transforms Fe^i into F^e to be added in the design description produced by process 12.

4.6 *Reformulation type 1*

Reformulation of structure addresses changes in the structure state space during designing. In the original FBS framework, the starting point of this process is an existing structure S, Figure 10(a), from which new structure variables are introduced in the structure state space. Yet, it cannot specify if this existing structure is external or internal to the design agent. The situated FBS framework, Figure 10(b), represents the provenance of new variables needed for reformulation in a more detailed manner, as it is capable of distinguishing between these two types of structure. Consequently, it shows two different processes, either one of which can trigger the reformulation of structure (process 9): the interpretation of external structure (process 13) and the construction of a memory related to structure (process 6). The push–pull representation of these processes makes more explicit the view of structure reformulation as exploration rather than just search.

Example:

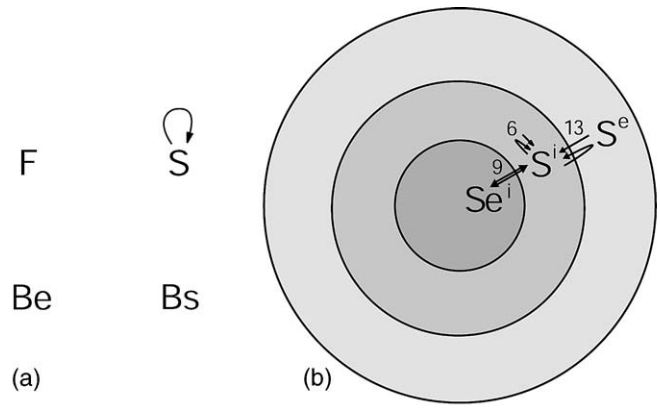

Figure 10 Reformulation type 1: (a) original, (b) situated FBS framework

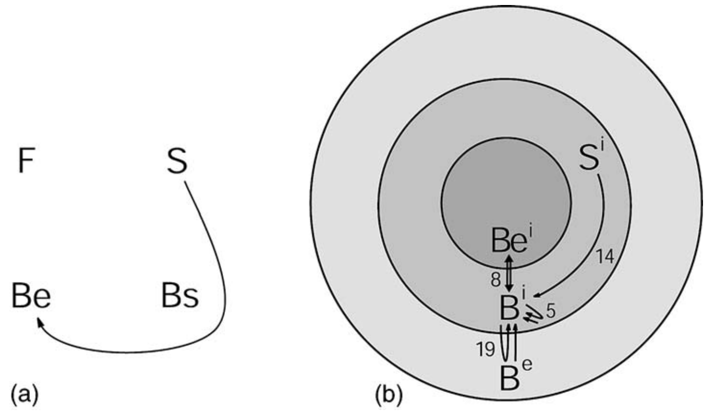

Figure 11 Reformulation type 2: (a) original, (b) situated FBS framework

–Process 9: allows both the addition of S^i into and the subtraction of Se^i out of the structure state space.
–Process 13: constructs new S^i from S^e. This construction represents a class of processes, which have been pointed out to include emergence, analogy, mutation, combination and first principles.[16] Some of these processes have been illustrated by Maher et al.[7] and Qian and Gero[8].
–Process 6: constructs new S^i from memory. It represents a class of processes similar to those described for process 13.

4.7 Reformulation type 2

Reformulation of expected behaviour addresses changes in the behaviour state space during designing. The original FBS framework, Figure 11(a), proposed only an existing structure as the generator for new behaviour variables. The situated FBS framework, Figure 11(b), provides a richer view on the reformulation of expected behaviour (process 8). Besides the derivation of interpreted behaviour from interpreted structure (process 14), it also depicts the interpretation of an external behaviour (process 19) and the internal construction of an interpreted behaviour (process 5) as the possible drivers of this type of reformulation.

Example:

–Process 8: allows both the addition of B^i into and the subtraction of Be^i out of the behaviour state space.
–Process 14: derives new B^i from S^i. Gero and Kazakov[17] have illustrated this process using an example from behaviour analogy where new behaviour variables are introduced into the target design based on structural similarity with the source design.
–Process 19: constructs new B^i from B^e. It represents the same class of

17 **Gero, J S and Kazakov, V** 'Using analogy to extend the behaviour state space in creative design' in **J S Gero and M L Maher** (eds) *Computational models of creative design IV*, Key Centre of Design Computing and Cognition, University of Sydney, Sydney, Australia (1999) pp 113–143

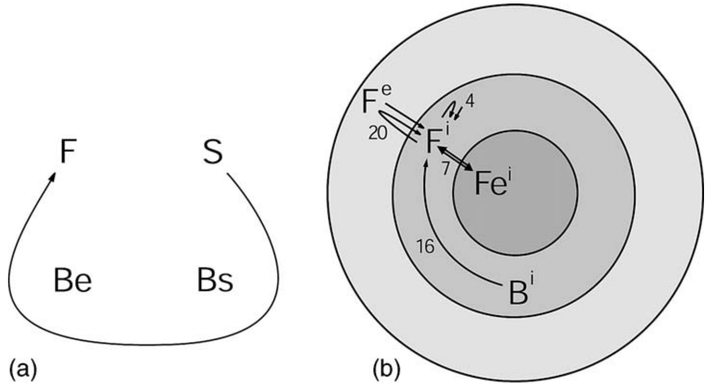

Figure 12 Reformulation type 3: (a) original, (b) situated FBS framework

processes as described for the construction of S^i (although they have been studied less for behaviour than for structure).
–Process 5: constructs new B^i from memory. It represents the same class of processes as described for the construction of S^i (although they have been studied less for behaviour than for structure).

4.8 Reformulation type 3

Reformulation of function addresses changes in the function state space during designing. The original FBS framework, Figure 12(a), commences only with an existing structure that generates new function variables via new behaviour variables. The situated FBS framework, Figure 12(b), proposes a larger number of processes that can drive the reformulation of function (process 7): the ascription of interpreted function to interpreted behaviour (process 16), the interpretation of external function (process 20) and the internal construction of an interpreted function (process 4).

Example:

–Process 7: allows both the addition of F^i into and the subtraction of Fe^i out of the function state space.
–Process 16: ascribes new F^i to B^i. Finke's[18] examples for emergent functions via reasoning about possible behaviours of a given structure can be seen as representing this process.
–Process 20: constructs new F^i from F^e. It represents the same class of processes as described for the construction of S^i (although they are amongst the least explored of all processes related to function).
–Process 4: constructs new F^i from memory. It represents the same class of processes as described for the construction of S^i (although they are amongst the least explored of all processes related to function).

18 **Finke, R** *Creative imagery* Lawrence Erlbaum, Hillsdale, NJ (1990)

5 *Conclusion: the situated FBS framework*

The reconstruction of the eight fundamental processes in designing in our situated world has brought about a set of processes, which can now be represented together, thus composing the situated FBS framework, Figure 13.

As can be seen, the number of processes depicted in the new framework, which is now 20, has risen steeply in relation to the previous number. This is a consequence of the capacity of the situated framework to deal with the agent's interaction processes with the external world and within itself, namely those of interpretation, constructive memory, focussing and action. The original FBS framework was unable to make these activities explicit. This was due to its restricted perspective, which could only represent processes involving transformations between the three different classes of design variables within one world (in terms of our three world model). An exception here was the explicit division between 'expected behaviour' and

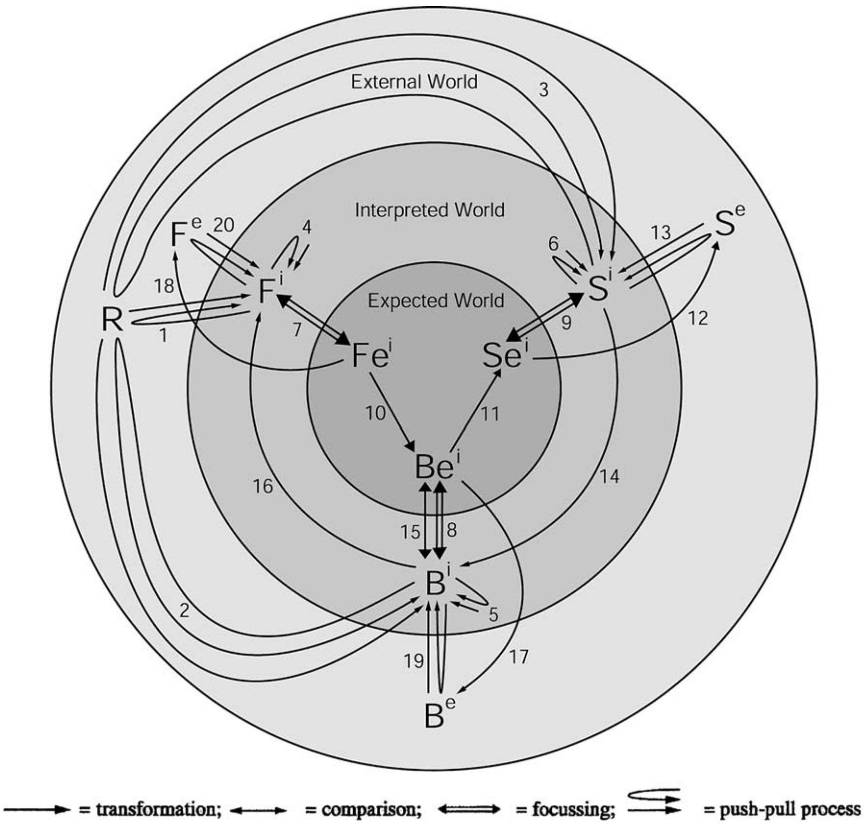

Figure 13 The situated FBS framework

‘behaviour derived from structure’. Although the scope of the latter term is too specific to cover all interpreted behaviour (B^i), this distinction fits into the conceptual idea of expected and interpreted worlds.

Our proposed augmentation of the original perspective can be viewed as the adoption of the viewpoint of an external observer of the design agent. Specifically, this external observer has knowledge about the agent’s construction, interpretation, focussing and action processes, which together make up the agent’s situatedness. The transformation processes between F, B and S (either in the expected or the interpreted world) that have been augmented by these classes of processes are represented using simple arrows instead of the push–pull symbols. This has been done in order to maintain the main purpose of the FBS framework to represent designing as a set of distinct transformation processes.

The overall achievement of the situated FBS framework as presented in this paper is its contribution to a better understanding of designing in an open, dynamic world. While still describing a set of distinguishable processes, conjointly mapping on to the eight fundamental processes specified in the original framework, it succeeds in integrating the idea of situatedness to allow it to be used in open worlds.

The situated FBS framework presented in this paper opens up a number of possibilities for future research. A new conception of design knowledge representation is conceivable, building on Gero’s[6] design prototypes. These are generalized schemas derived from sets of like design cases, which unite all the relevant knowledge necessary for designing. Making these design prototypes situated would enhance their applicability in dynamic design contexts.

This framework provides a new foundation for the development of intelligent agent-based design systems. This is mainly because it brings together important concepts of situated agents (like interpretation, focussing and constructive memory) and the three basic variables function, behaviour and structure making up the design world. This ability to deal also with design concepts like behaviour and function, besides structure, can make situated design agents potentially powerful enough to support human designers in the conceptual stages of designing.

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International Conference on Artificial Intelligence in Design'02 in Cambridge, UK.[19]

Notes

[1] We use the term 'internal world' to denote the interpreted world including the expected world.

19 Gero, J S and Kannengiesser, U 'The situated function–behaviour–structure framework' in **J S Gero** (ed.) *Artificial intelligence in design'02*, Kluwer, Dordrecht (2002) pp 89–104