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METHODICAL DESIGN 1972 –INTEGRAL DESIGN METHODOLOGY 2007: MORPHOLOGIC REFLECTION

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1. Introduction

Design, as a solution-evolving process, involves activities of searching, analysing, manipulating and structuring information about the problem to be solved. Generating new information, and evaluating and communicating information are major activities within the process. Design normally has a very dynamic nature, with a tendency to ad hoc actions, which should be supported by design aid systems. Sometimes design is considered a mainly problem solving activity where the need transformed to a design problem and its solutions co-evolve. The result of this activity, the product model is frequently called 'a design' i.e. a complete description of the object to be built. As complexity and scale of design processes increase, as well as the demands on these processes with respect to costs, throughput time and quality, traditional approaches to organize and plan these processes may no longer suffice (van Aken 2003). As a result between 1945 and 1965 there was a shift in focus towards process models of design. Models from this period are characterized by their focus on detail and their lack of dealing explicitly with requirements (Blessing 1994). In the mid-80's the focus moved more towards descriptive design methodologies. Descriptive design methodology focuses on the 'description of a sequence of activities that typically occur in design' (Cross 1989). Design research focuses more on empirical studies of design: originally on detailed studies of individual design behaviour and more recently on group design behaviour of design teams. Good overviews of the field of Design Research are provided by different authors (Bayazit 2004, Horvath 2004).
To support the design of large-scale, complex products, methods are needed to support the complex design process by structuring it. It is assumed that designers survey a problem, form a judgment about critical areas in the design matrix and make decisions about how the focus of attention may be optimized. By introducing a descriptive element from the reflective practice in the prescriptive model of Methodical Design a new Integral Design method is introduced. The resulting Integral Design methodology (IDM) makes it possible to work in a structured and transparent way using the framework of the resulting design matrix. It is for the designer to make the decision about which elements of the design method matrix he wants to use. Starting from a prescriptive model, Methodical Design, we are developing the relationship between rational problem solving and reflection in action.

2. Methodology

2.1 Methodical Design

Early seventies in Netherlands a methodology was developed to teach design to mechanical engineers at the faculty of Mechanical Engineering Technical University Twente at Enschede; Methodical Design model from van den Kroonenberg (1974). From the start Methodical Design facilitated teaching and transfer of design methods to industry. The Dutch Royal Society of Engineers(Kivi) had its own course of professionals in 1974. It is an approach with typical and exceptional characteristics (Blessing 1994):

- it is a problem-oriented approach
- it is the only model emphasizing the execution of the process on every level of complexity
- it is one of the few models explicitly distinguishing between strategies, stages and activities

The Methodical Design approach was elaborated theoretically by de Boer (1989) and Blessing (1994). Methodical Design distinguishes, based on functional hierarchy, various abstractions or complexity levels during different design phase activities. Methodical Design makes it possible to link these levels of abstraction with the phases in the design process itself. Methodical Design is based on the combination of the German design school (Matousek, Hansen, Roth, Hubka, Pahl, Beitz) and the Anglo-American school. (Hall, Asimov, Archer, Greogory, Krick, Jones).

Though the Methodical Design model is one out of a great variety of design models it is the only method to make a distinction between phases and levels (Blessing 1994). The three main phases which are distinguished are; defining the problem, determining the working principle and detailing the design. The levels are a distinction based on a hierarchy of complexity. The design phases and complexity levels form the main elements of the structure or framework of Methodical Design (de Boer 1989), see figure 1E.

Methodical Design was investigated mainly by teaching and it led to a wide range of applications. Besides two PhD theses, over 170 MSc. theses and 25 BSc. theses at the Technische Universiteit Twente (TUT), there are many students reports on practical assignments in industries, that have been conducted as part of a design course (de Boer 1989). Furthermore there are over 100 reports on design activities of the staff on the projects that have been carried out in the fields of; underwater technology, non-waste technology, wind pumps for developing countries and bio-medical devices. Methodical Design is considered suitable to be used and taught as a way to solve engineering problems more easily by (de Boer 1989);

- providing a basic problem solving approach for engineering;
- flexibility, because it can be used in many different applications;
- effectiveness, as it assists in obtaining suitable results.

Also systematic feedback on the use and teaching Methodical Design (de Boer 1989);

- enables novices to apply it without much difficulty;
- enables further development by students themselves, depending on their own ideas and preferences;
- stimulate professionals to use and adapt it.

At present Methodical Design is still taught at many of the Technical High Schools in the Netherlands. Many applications can be found in Dutch industry; two innovative successful companies, Nefit and Biddle use Methodical Design in their product development design.

Integral Design is presently taught at the faculty Architecture, building and planning in the course on Design methodology of Technische Universiteit Eindhoven and in the Master of Building Services Engineering course of the post Higher Technical Education program of the Avans Hogeschool in Den Bosch.

2.1 Extension to Integral Design

A basic three-step pattern, the basic cycle, can be recognized within each phase of the Methodical Design process, see fig. 1B. The origin of this three-step pattern is given by van den Kroonenberg referring to the general systems theory, see fig. 1A. As the relation between the general systems theory is not worked out completely within Methodical Design, the basic design cycle is extended by us and the phases are renamed more fittingly to the specific design activities, see fig. 1C.

In addition to the design matrix presented by de Boer (1989), we constructed an extended design model; the Integral Design (ID)-methodology. In the ID-methodology the design process matrix, the cycle (define/analyse, generate/synthesize, evaluate/select, implement/shape) forms an integral part in the sequence of design activities that take place. The ID-methodology design matrix provides an overall structure that makes the basic design cycle recognizable as such. An essential difference with the former approach is the shaping phase after the selection phase, in which the decision about the transformation to a lower level of abstraction takes place and the design is modified, developed and further shaped, see fig. 1.

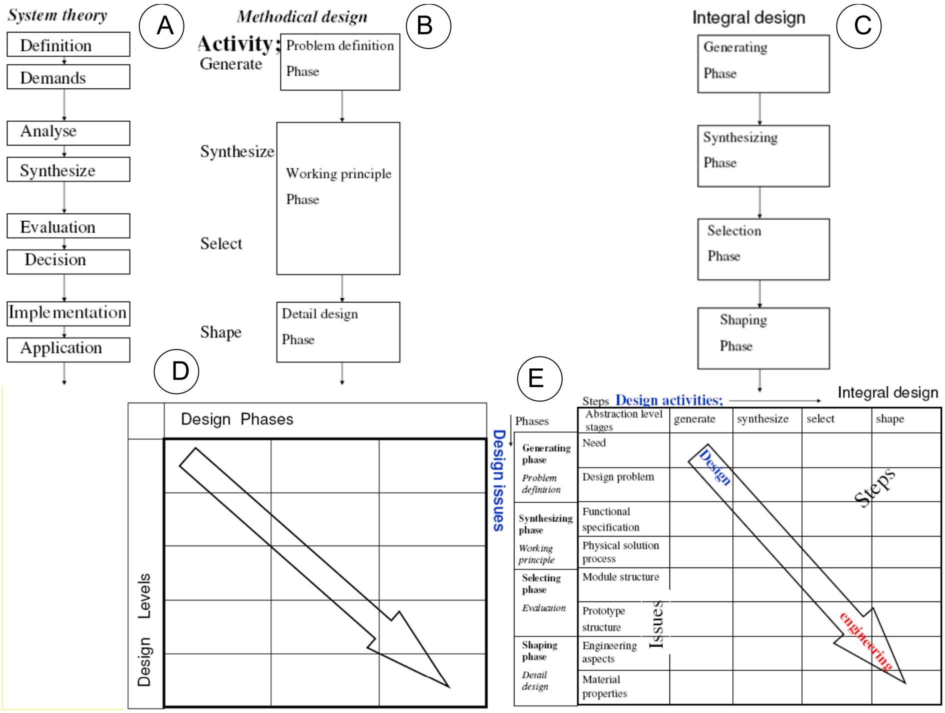

Figure 1. The pattern of System theory (A) , basic three-step pattern of Methodical Design (B), the four step pattern of Integral Design (C) and their design method/ contents matrix indicating the phases, abstraction levels, issues and steps (D) and (E)

The method/contents matrix represents the recursion of the design steps of a design process from high abstraction level to lower abstraction levels. In the matrix the four main phases can be found as well as the four-step pattern. The separate steps can be listed organized by abstraction level and design phase. These steps results in a complete framework of connected levels of complexity or abstraction. Abstraction is the selective examination of certain aspects of a problem and helps the designer to decompose a complex design question into problems of manageable size. By introducing different levels of abstraction the designer can limit the complex design question to smaller sub-questions. The design task can be viewed on each individual level of abstraction. The emphasis at higher levels of abstraction lies on the problem definition phase and generation, while at lower levels of abstraction the emphasis is on developing details of the design product. The design phases and abstraction levels form the dimensions of ID methodology method/contents matrix.

Functions can be regarded as what a design is supposed to fulfil: the intended behaviour or intended characteristics of the object. Functions have a very significant role in the design process. An important decomposition is based on functions. Generally, designers think in functions before they are concerned with details. During the design process, and depending on the focus of the designer, functions exist at the different levels of abstraction. Besides, the definition of functions during interpretation of design task makes it possible to assess client's needs on a higher, but better workable, abstraction levels than the program of requirements provides. Based on definition of functions, various design complexity levels can be separately discussed and, accordingly, possible solutions generated. This way interaction with the client is aided, and at the same time the design process can structured by giving an overview of the considered functions and aspects and their solution alternatives, this is called a morphological overview (Zwicky & Wilson 1967). The morphological overview gives a complete overview of aspect elements or sub-solutions that can be combined together to form a solution, see fig.2.

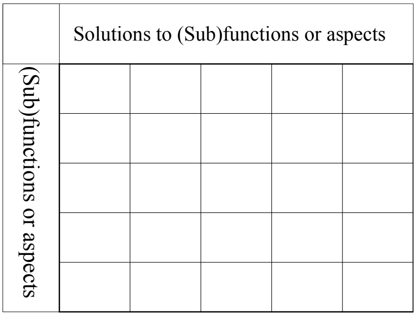

Figure 2. The morphological overview

Function-oriented strategy, preferred by experienced designers (Fricke 1993), allows various design complexity levels to be separately discussed and, subsequently, generated (sub)solutions to be transparently presented. This way the interaction with the other participants of the design process is aided, and at the same time design process information exchange is structured.

3. Connecting Integral Design and Reflective Practice

The framework of Integral Building Design can be seen as a representation of a rational problem solving view of designing and was further developed. The rational problem solving paradigm presumes objective criteria for design. The focus lies within this paradigm on objective interpretation of essentially ill-defined design problems (as they are widely accepted to be); in order to be able to rigidly organize design processes. The objective interpretation of fundamental unique problems is however not possible. The approach of reflective-practice (Schön 1983) describes the tackling of fundamentally unique problems. Schön proposes an alternative epistemology of design practice, which describes design as ‘reflective conversations with the situation’ (Reymen 2001).

The combination of aspects of reflective practice during the interpretation phase, and rational problem solving methods, during the conceptual design phase, will help to overcome the major obstacle: a definition of ‘designer objective’ criteria, as a prerequisite for effective actions during design processes. By the use of reflective structures problem solving process of ID methodology is combined with the reflective practice of Schön (1983). In applying Integral Design it is not always important to go through a complete design process on each level of complexity. Often the focus can be on specific steps on specific hierarchical abstraction levels. As a result integration of a prescriptive matrix and a descriptive / reflective focus on its use results in a virtual connection between the different approaches, see figure 3.

Integral Building Design is an example of integration between rational problem solving and the theory of reflective practice of Schön (1983).

Designing takes place in an environment that influences the process so it is contextually situated. The context of the model of designing is defined by a “world view”. The model of de Vries (1994) consists of 3 worlds and is extended by us to four worlds: the real world R, the symbolic world S, the conceptual world C and the specification world M, see fig. 4 left part. Separation is made by us between:

- Information level, knowledge-oriented, representing the "conceptual world".
- Process level, process oriented, representing the "symbolic world".
- Component level, device orientation, representing the "real world".
- Part level, parametric orientation, representing "the specification world".

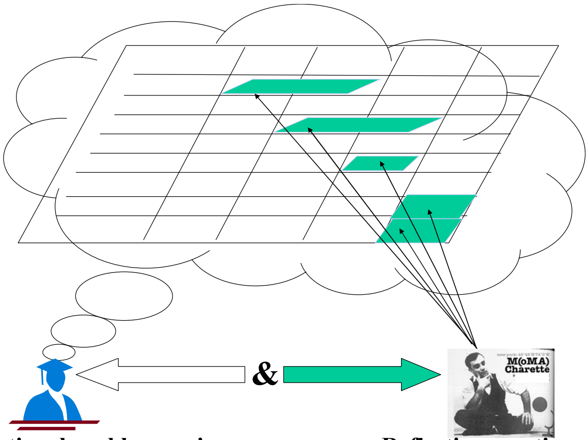

Figure 3. The relation between rational problem solving and reflective practice

Thus, the four levels of aspect abstraction in our descriptive model of design are:
1. Information Level
This level deals with the experts' knowledge of the systems. One of the essential ideas behind this is that human intelligence has the capability of search and the possibility to redirect search. This information processing is based on prior design knowledge.
2. Process Level
This level deals with physical variables, parameters and processes. The set of processes collectively determines the functionality of the variables that represent the device properties. Modelling at the functional level involves the derivation of an abstract description of a product purely in terms of its functionality. This abstraction reduces the complexity of engineering design to the specification of the product's desired functionality.
3. Component Level
This level describes the hierarchical decomposition of the model in terms of functional components and is domain dependent. Generic components represent behaviours that are known to be physically realizable. They are generic in the sense that each component stands for a range of alternative realizations. This also implies that the generic components still have to be given their actual shape.
4. Part Level
This level describes the actual shape and specific parameters of the parts of which the components exist. Relevant technical or physical limitations manifest themselves in the values of a specific set of parameters belonging to the generic components. These parameters are used to get a rough impression, at the current level of abstraction, of the consequences of certain design choices for the final result.
One of the major problems in modelling design knowledge is in finding an appropriate set of concepts that the knowledge should refer to, or -in more fashionable terms- an ontology (Alberts 1993). An ontology means in philosophy theory of existence: it tries to explain what is being and how the world is configured to account things and their intrinsic relations. It is an explicit specification of a set of objects which the observer thinks exist in the world of interest and relations between them as stated by Grüber (Kitamura 2006). Research in the ontology of design speculates about things on the basis of their being thought (Horváth 2004). The relation between the extended model of de Vries (1994) and our conceptual model is shown in fig. 4.
Here a descriptive element in the prescriptive model is introduced by us. By using the morphological overview as a tool for visualization of the interaction we introduce a reflective element within the Integral Design approach, see fig. 5. Integral Design is an example of integration between rational problem solving, of which Methodical Design as basis of Integral Design, is a good example, and the theory of reflective practice of Schön.

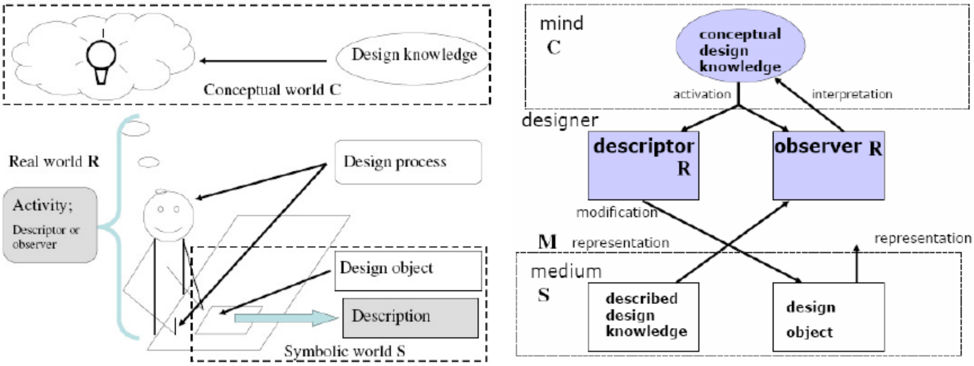

Figure 4. Designer and World view and extended model analytic schematic interaction model of designing

The combination of aspects of reflective practice during the interpretation phase, and rational problem solving methods during the conceptual design phase, will help to overcome the major obstacle: a definition of 'designer objective' criteria, as a prerequisite for effective actions during design processes.

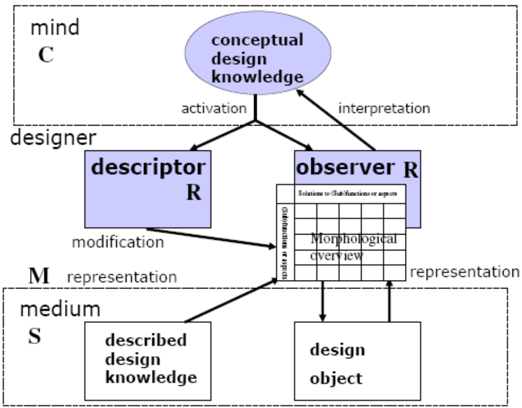

Figure 5. Extended model with the morphological overview as tool for representation and modification

As stated by Lloyd (1995, p.259) there are many methods of investigating the design process and each has salient features: "Interviews, retrospective reports, concurrent reports, teaching, and introspection all have something to contribute to an empirical understanding of the design process. What one should then look for is consistency in the results that each method offers." The use of Morphological Overviews as a prescriptive design tool and as a reflective instrument as such offers consistency.

4. Discussion

The approach by van den Kroonenberg is similar to the Integrated Product Development (IPD) by Andreasen (Andreasen and Hein 1987, Buur and Andreasen 1989). Still Methodical Design has some special characteristics; " it is one of the few models that explicitly distinguishes between stages and activities, and the only model that emphasis the recurrent execution of the process on every level of complexity (Blessing 1993, p.1398)". Especially the horizontal dimension is not strongly represented in other familiar design models and thus tends to be forgotten (Roozenburg and Cross 1991, p. 216);

"not so much by its authors (see for instance Pahl and Hubka) but by its users and, above all, its critics, leading to faulty arguments and misinterpresentations of the model ."
The context of the model of designing is defined by the "world view" based on the extended model of de Vries (1994). This model is similar to the chromosome product model by Malmqvist as adapted from Andreasen. In that model there are besides the specification, the process structure, the function structure, the organ structure and the component structure (Malmqvist 1995).
Integral Design should not be considered as a recipe for all processes, but it is a good recipe to learn cooking. Gradually designers will modify the method they use and improve it. Integral Design should be a set of rules with which designers can start, as well as improve upon.

5. Conclusion

By extending Methodical Design into a new Integral Design-methodology is introduced. The resulting ID-methodology makes it possible to work in a structured and transparent way using the framework of the resulting design matrix. This design matrix is used as a kind of mental frame work enabling the designers to use it to support structuring his thoughts and actions. It is assumed that designers survey a problem, form a judgment about critical areas in the design matrix and make decisions about how their focus of attention may be optimized. So it is for the designer to make the decision about partly use of the matrix elements of the design method. By introducing a morphological overview as a descriptive element for reflective practice in the prescriptive model a true connection between prescriptive and descriptive methodology is made: Morphologic Reflection. Through visualization of contributions within a design team, morphological overviews can show how (integral) design concepts are emerging within design teams. By structuring design (activities) and communication between design team members, morphological overviews form the basis for reflection on the design results; both by the design team members themselves and in discussion with external parties such as the project manager. Through the application of the integral design method each step within the design process becomes transparent, which makes it possible to reflect on all the decisions made and all the alternatives considered along the design process.

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