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Instant Set-Based Design, an Easy Path to Set-Based Design

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Abstract

A simplified variant of Set-Based Design (SBD) was created. It was combined with the creative methods 6-3-5 and the Gallery method as well as the systematic method morphological matrix to generate solutions. This made it possible to introduce SBD in one day, which has been verified by tests on design problems at industrial firms. The methodology, Instant Set-Based Design (ISBD), was perceived easy to understand and was well received by the designers. The introduction of it was less cumbersome compared to the full version of SBD. The conclusion is that the developed methodology works as intended with good results.

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Keywords: Set-Based Design; Lean; Product Development; Design; Creative Methods

1. Introduction

Several authors prescribe a process with common steps to take when developing products. Descriptions are found in literature by Pugh [1], Ulrich and Eppinger [2], Pahl et al. [3] among others.

A development methodology that uses a different approach compared to the processes above is Set-Based Concurrent Engineering (SBCE) [4, 5], or, more generally, Set-Based Design (SBD). One of its characteristics is to explore the design space by developing multiple solutions and rejecting iterations as a prescribed means to improve task descriptions, requirements lists, concepts and designs. SBD instead uses a converging, parallel process with proven feasibility to narrow descriptions of requirements, designs and manufacturing systems to arrive at a final solution, see Figure 1. One means in SBD is to produce reusable knowledge to prove feasibility. It has received positive attention and some authors claim that SBD and related practices from Lean Development are four times more productive than conventional development models [4, 5].

SBD is however challenging to introduce for several reasons. It is usually considered incompatible with traditional phased project models [5, 6], which are common ways to organize an industrial development process. Another challenge not described in the literature is how to generate the multiple alternatives that are central in SBD. Furthermore, there is little guidance on how to deploy SBD in practice.

To overcome the abovementioned difficulties, a new simplified approach coined Instant Set-Based Design (ISBD) is presented where the SBD process is streamlined and supplemented with methods for creativity, systematic concept generation and design evaluation. The objective of this research is to develop a methodology to present SBD in one day, thereby facilitating an easier introduction of the methodology and support the existing design processes.

The research question we pose is: *Can a Set-Based Design process combined with creative and systematic methods for concept generation be efficiently introduced in an industrial environment in only one day?*

2. State of the art

The state of the art is limited to the field of Set-Based Design, and to established creative and systematic methods that are suitable for industrial settings, i.e. possible to perform within a short period of time.

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2.1. Set-Based Concurrent Engineering and Set-Based Design

In conventional development as described by Ward & Sobek [4], here called Point-Based Design (PBD) as stated by Ward et al. [15], a single design solution is selected early, when the knowledge and understanding of the problem is low. This single design is then iteratively re-worked and improved until a feasible solution is arrived at.

Set-Based Concurrent Engineering has received positive attention for its emphasis on the importance of studying alternative design solutions and variations of them referred to as "sets of solutions", hence Set-Based. SBCE is also known for its distinctive process of parallel evaluation and gradual narrowing of the requirement description, the design space and the manufacturing system design space. See Figure 1.

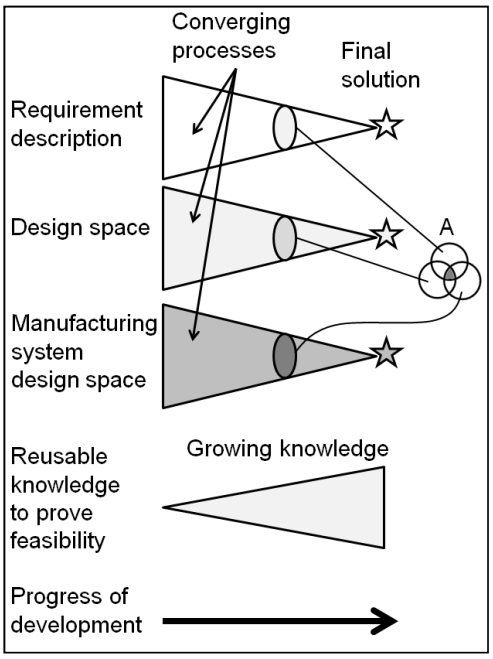

Figure 1. In SBCE, the requirement description, the design space and the manufacturing system design space are gradually narrowed in parallel as more knowledge is gained. After Ward [15]. In A integration is done by intersection of feasible regions.

It enables designers to reason about regions of the design space by communicating the constraints of different solutions, and it has a convergence process for arriving at a final design in parallel with increasing understanding of the problem through the creation of reusable knowledge. Set-Based Design is the activities used to designing according to the principles of SBCE. The principles are given in Table 1.

In SBD [7], no single design solution is selected in the early phase of development. Instead, convergence towards a solution is achieved by testing and learning about the different alternatives. Unfeasible alternatives are eliminated and feasible regions in the design space are narrowed based on facts from tests or other sources of validated knowledge. SBD emphasizes learning and the creation of reusable knowledge [4].

Table 1: The three principles of Set-Based Concurrent Engineering. After Sobek et al. [16].

Principle	Stage	Description
I	Map the design space	Define feasible regions Explore trade-offs by designing multiple alternatives Communicate sets of possibilities
II	Integrate by intersection	Look for intersections of feasible sets Impose minimum constraint Seek conceptual robustness
III	Establish feasibility before commitment	Narrow sets gradually while increasing detail Stay within sets once committed Control by managing uncertainty at process gates

2.2. The 6-3-5 method

In design theory, Pahl et al. [3] present solution-finding methods. Two of these are intuitive methods: the 6-3-5 method and the Gallery method. In the 6-3-5 method, six participants each create three solutions to the problem and then pass them on to their respective neighbor, who further develops them. This goes on until the solution returns to the original creator and has been processed by the other five participants, hence the name 6-3-5.

2.3. The Gallery method

In the Gallery method [3], a group of persons work on the same problem by sketching solutions on separate sheets of paper. The sheets are then posted on a wall for all involved to see and discuss. A second round of solution creation and posting on the wall is then performed. The last activity is the selection step where promising solutions are identified.

The concept generation phase is described by Ulrich and Eppinger [2] as a five-step method in which team knowledge and creativity is one means of generating concepts. Tools in this are analogies, wish and wonder, related and unrelated stimuli, setting of quantitative goals and the Gallery method.

2.4. Morphological matrix

The morphological matrix was introduced by Zwicky, as reported by Pahl et al. [3]. It is a systematic presentation of information and data that illustrate the possible combinations of partial solutions that can make up overall solutions. An example is given in Table 2.

The partial solutions to a function are written on the same row in a matrix. The general idea is to generate one or several overall solutions by selecting one solution from each row which are compatible with each other.