Design and VR/AR-based Testing of Advanced Mechatronic Systems

Jürgen Gausemeier, Jan Berssenbrügge, Michael Grafe, Sascha Kahl and Helene Wassmann
Heinz Nixdorf Institute, University of Paderborn, Germany

Abstract

Advanced mechatronic systems with inherent partial intelligence, so-called self-optimizing systems, react autonomously and flexibly on changing environmental conditions. Such systems are capable of learning and optimizing their behavior during operation. Their principle solution represents a significant milestone because it is the result of the conceptual design as well as the basis for the concretization of the system itself, which involves experts from several domains, such as mechanics, electrical engineering/electronics, control engineering and software engineering. Today, there is no established design methodology for the design of advanced mechatronic systems. This contribution presents a new specification technique for the conceptual design of advanced mechatronic systems along with a new approach to manage the development process of such systems. We use railway technology as a complex example to demonstrate, how to use this specification technique and to what extent it facilitates the development of future mechanical engineering systems. Based on selected virtual prototypes and test beds of the RailCab we demonstrate, how VR- and AR-based approaches for a visual analysis facilitate a targeted testing of the prototypes.

Keywords

Mechatronics, Self-Optimization, Design Methodology, Principle Solution, Targeted Testing, Virtual Prototype, Visual Analysis, Virtual / Augmented Reality

1 Virtual Prototyping in the Product Innovation Process

Products and manufacturing systems of mechanical engineering and its related industrial sectors like automotive engineering are getting more and more complex. Time-to-
market is decreasing simultaneously. Under these circumstances the product innovation process is facing extraordinary challenges. Before we point out how to overcome these challenges, let us spend a brief look on the product innovation process.

The product innovation process starts from the idea of a product or business and leads to the successful product launch. It incorporates the areas of product planning, R&D and manufacturing process planning. The general work flow is shown in the figure. In practice, the product innovation process is iterative and comprises a number of cycles (see Fig. 1).

**The first cycle** characterizes the steps from finding the success potentials of the future to creating the promising product design, what we call the principle solution. There are four major tasks in this cycle:

- foresight
- product discovering
- business planning
- conceptual design

The aim of **foresight** is to recognize the potentials for future success, as well as the relevant business options. We use methods such as the scenario technique, Delphi studies and trend analysis.

The objective of **product discovering** is to find new product ideas. We apply in this phase creativity techniques such as the Lateral Thinking of de Bono or the well-known TRIZ.

**Business planning** is the final task in the cycle of strategic product planning. It initially deals with the business strategy, i.e. answering the question as to which market segments should be covered, when and how. The product strategy is then elaborated on this basis. This contains information:

- on setting out the product program
- on cost-effectively handling the large number of variants required by the market
- on the technologies used and
- on updating the program throughout the product lifecycle

Additionally, a business plan must be worked out to make sure an attractive return on investment can be achieved.

This first cycle is also concerned with the **conceptual design**, although this area of activity is actually assigned to product development in the strict sense. The result of the conceptual design is the principle solution. It is, for example, required to determine the manufacturing costs needed in the business plan. That is the reason why there is a close interaction between strategic product planning and product design linked by conceptual design. Conceptual design is the starting point for the next cycle.

**This second cycle** corresponds to the established understanding of product development. The essential point here is the refinement of the cross-domain principle solution by the domain experts involved, such as mechanical engineering, control technology, electronics and software engineering. The results elaborated by the domains in this cycle must be integrated into an encompassing product specification. This specification has to be verified in the light of the requirements given by the first cycle.