Chapter 16
Conclusions

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The authors hope that readers of the book have enjoyed the fundamental research topics and future visions of the contributors to the text. This chapter reflects the interaction and integration of these major topics and tries to summarize the key statements.

It should be pointed out that the continuous (r)evolution of the technical (mechatronic) systems with the deeper integration of multiple disciplines (e.g. IT functionalities and components) and the detailed consideration between the products and their related production processes are parts of the major trends in product design. Furthermore, the involvement of several partners (all over the world) and the challenges of new business process play an important role.

16.1 Global Trends and the Impact on Mechatronics

An overview on global (mega) trends has been provided by several institutions in recent years (e.g. see [1]). They differ from each other in detail, but the major topics are involved in all published studies as follows:

- Demographic change (and ageing society, healthcare systems)
- Mobility
- Globalization (and changes in the work world, economy, finance)
- Urbanization (and individualization)

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P. Hehenberger and D. Bradley (eds.), *Mechatronic Futures*,
DOI 10.1007/978-3-319-32156-1_16

- Climate change and environmental change (and Energy and resources, sustainability)
- Knowledge-based society (and ubiquitous intelligence, digital culture)

For manufacturing production in 2030 the following four major topics are discussed by Westkämper [2]:

- Innovative products and processes
- Knowledge-based manufacturing engineering
- New business models in the life cycle of products
- Infrastructure and education

The result of all these trends is also that the technology has to push forward. So there are high product development potentials in mechatronics due to the combination of multiple disciplines, as discussed in the chapters of this book.

One major part of economic success is the development of innovative products and processes. The term innovation comprises invention, introduction and sales of a new product, service or procedure [3]. This does not only include the whole marketing process, but also the social and economic impact. Irrespective of the quality of the invention many, factors influence the growth of an invention into an innovation. The main factors discussed in this context can be split into three groups of technological, economical and social influences (see global trends [1, 2]). The field of mechatronics is known to be the source of numerous innovations. However, most new developments are identified as incremental innovations. Conceptual design has been identified as the most critical phase in product design in context with radical innovations as the main portion of success will be established there.

Decisions made in this early stage have a superior influence on the future development of the product. Therefore, the definition of the requirements on the system level for the overall product is crucial. The requirements which are defined on the system level should reflect the customer's wishes. To ensure that the system under consideration meets the requirements, it is necessary to translate them into properties of the solution. The development of systems merges solutions from disparate engineering disciplines, like mechanical engineering, electrical engineering, control engineering, etc. So it is very important to distinguish between properties which can only be assured on the system level and those which can be assured by a single engineering discipline. Hence, it is important to assign the different properties to the relevant level [4]. For achieving this task models on the different hierarchical levels are necessary (discipline-specific model and system models). From this point of view the modelling, simulation, evaluation and optimization of the considered specific aspects are key points for future mechatronic systems design, as is also mentioned in several of the previous chapters.

16.2 Mechatronic Futures Map

It is understandable that it is not possible to discuss all aspects of *Mechatronic Futures* in "one" single book. The goal in this book is how to group the challenges into main subjects and present specific aspects from different viewpoints. The common viewpoints and perspectives are identified below, while Fig. 16.1 shows the map of the following topics:

- *Issues and Challenges*
  The main driver for future evolution of mechatronic systems is the reduction of development costs and time as well as the improvement of the designed products using new technologies. This deals mainly with the virtualization of the product to improve its architecture design, its verification and validation, its production or operation. Indeed, virtualization enables more flexibility in the different stages of the development at lower cost. The interaction between the designed product and the production systems plays an important role in the direction of Industry 4.0 (or Smart Manufacturing, Cyber Physical Production Systems, etc).
- *System Design, Modelling and Simulation*
  Mechatronic products gain a more complex structure and will have more computing power and network connectivity. This leads to the extended design challenges in understanding the difficulties of complex systems where simulation will be a

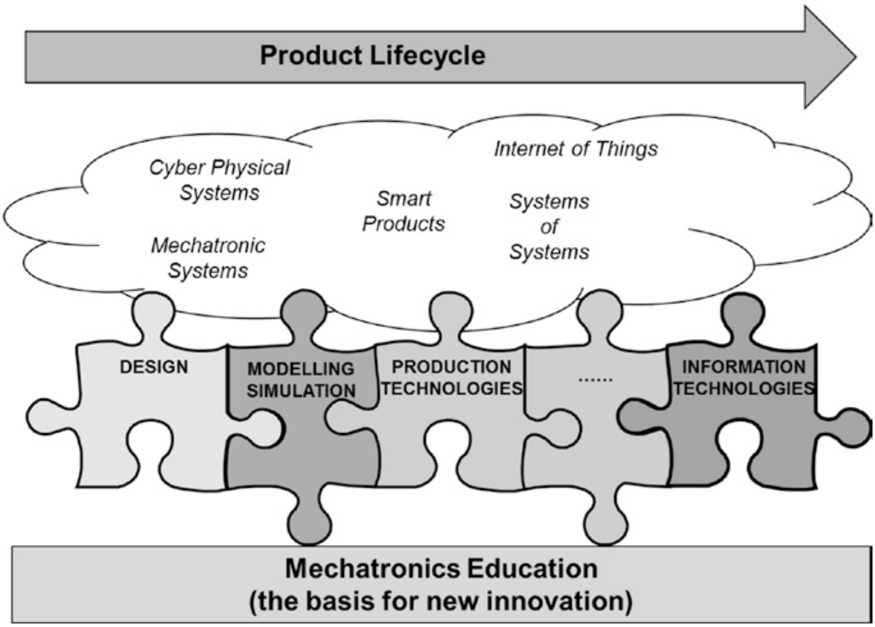

Fig. 16.1 Mechatronic futures map

key technology for mastering these. The future trends, methods and models for the design processes of mechatronic systems have to be considered as unquestionable enablers for transformation of complex systems into cyber physical systems or the global integration of the internet of things. These design processes for mechatronic engineering have to support the development of the new services or the implementation of an industrial internet for the factories of the future.

- *Manufacturing Technology*
  Future technologies (e.g. Additive Manufacturing or AM) for physically creating mechatronic devices and systems will enable new possibilities in the design process. There will be a shift from "*design for assembly*" approaches to "*direct manufacturing*" approaches. So we could remove the need for post-fabrication assembly and use of fastenings, yielding rapid production of robust devices. Nowadays typical examples are 3D printed sensors, 3D printed electronics and integrating multiple materials, which is the basis for the production of "*Fully Integrated Mechatronic Devices.*"
- *Internet of Things and Cyber Physical Systems*
  The current trend in mechatronics involves the deeper integration of computation and physical processes in networked mechatronic systems, cyber physical systems (CPS) or Internet of Things (IoT). Therefore communication, integration and data analysis are considered essential since the scope for IoT will depend upon the consolidation of diverse systems and standards, with "*lower level*" (local) systems talking to each other and to "*upper level*" (global) systems. Typical applications are home automation, production, transport, energy, health care and agriculture. The lauded potential social and economic benefits are plausible but not guaranteed yet.
- *Communication and Information Technologies*
  The key issues here are associated with the need to facilitate the formation of multidisciplinary partnerships. Without such partnerships, opportunities to innovate in both product design and service delivery may well be lost. Consequently, organizations that establish robust forms of partnership working are more likely to secure a competitive advantage. Associated with this is a requirement to establish new methods of securing and managing user consent, while ensuring no economic or functional disadvantage if a user opts out of data sharing.
  This leads in turn to questions as to how to educate and inform technologists, along with legal/jurisprudence practitioners, so that legal and societal demands are addressed in the development, implementation and application of new technologies.
- *Mechatronics Education*
  Mechatronics is moving to a future where the design of complex physical components is becoming commoditized. The particular challenge is that of subject diversity and mechatronics education must therefore aim for a balance between "*Technical knowledge*", "*Underlying fundamental technical skills*" and "*Personal skills*" and any educational programme should be oriented to support these areas. Typical topics, which have to be covered by mechatronics courses

are aligned along the product life cycle, including innovation, creativity, systems thinking, engineering and integration used a combination of project- and problem-based learning methods. Mechatronics education is then the base for applying newly available technologies.

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