

Preface

This is the translated English edition of the book “*Systementwurf mechatronischer Systeme*” published by Springer in January 2010. For the motivation, background and concept of presentation, the obliging reader is referred to the preface of the German edition, which follows.

Already in the course of preparing the German book and studying the vast literature in this subject area, I recognized that there still exists some room on the international mechatronics stage for the material presented in this monograph. Moreover, the many positive comments of colleagues and students on the German edition encouraged me to think of starting a second round with an English edition.

From the very beginning, it was clear to me that such a project could only be successful with translation support from a native speaker having broad and excellent knowledge of engineering, and particularly mechatronics. Luckily, a previous stay at the Stanford Aerospace Robotics Lab brought me into contact with the best possible partner for this purpose: Dr. *Kristof Richmond*. As a fully bilingual native speaker, a highly qualified Stanford graduate, and an intelligent, critical, and altogether most clever scientific partner, he combines all of the talents which I did not really expect to find in one person. The joint work on this English edition was therefore extremely smooth, mutually enriching, and, in the age of internet and Skype, never bounded by the cross-Atlantic separation between Germany and Iowa. A big thanks to Kristof for this great job.

This English edition covers the contents of the German edition with some minor improvements in presentation, with updated English textbook bibliography, and it gave us the chance to remove errata found in the German edition.

For the acknowledgements in putting together this mass of material, the reader is again referred to the subsequent preface of the German edition. Nevertheless, I must acknowledge two people in the context of this English edition. My first thanks go to my beloved wife *Ruth*, who has also supported and accompanied this second mountain climbing expedition with a fantastic and ever-encouraging mood (though fortunately, this was a

much lower summit than the previous one, cf. preface to the German edition).

My thanks and commemoration go also to *Martin Beck*, who tragically died in February 2011 just before finishing his PhD. As one of my most talented PhD students and closest co-worker in my mechatronics courses, he provided major contributions in the critical proofreading of the original material, sound and always critical technical and scientific discussions, and numerous recommendations for improved didactic presentation. His spirit will also remain between the lines of this English edition.

Last, but not least, all the aforementioned efforts would not have resulted in the present book without the valuable support, trust, and the excellent service of the Springer publishing team represented by *Eva Hestermann-Beyerle*.

Dresden, June 2011

Klaus Janschek

Preface – German Edition

Motivation

Why another book on mechatronics? And moreover, why such a comprehensive volume with so much descriptive text?

I had answered the first question for myself at the beginning of this project with the justification of “*re-working my apprenticeship*”, whence I derived the motivation for its realization—whose extent could not be guessed at the time. The second question only presented itself in the course of composition, and was answered in cases of doubt by making decisions in favor of more text following the paradigm “*everything need not be hidden between the lines and in the formulae*”.

Now, to the story of “the apprenticeship”. This began with me as an *electrical engineering student* at the Graz University of Technology (TU Graz), from which I obtained a very serviceable foundation in mathematics and the natural sciences—as should after all be expected of a university course of study in engineering. A major and then a doctorate in control theory subsequently uncovered to me a view of “systems” and systems-oriented solutions.

My subsequent apprenticeship as a *development engineer* in mechanical engineering and in aerospace led me to application areas which had played practically no role in my studies: complex heterogeneous systems, which today would be called “mechatronic systems”. That my entry into this domain was still quite successful is probably due to two things: the broad foundation provided by my university education, and a systems-oriented approach to solving problems.

Alongside fascinating experiences involving challenging new applications, these years of apprenticeship produced an important *realization*: “You must learn to bring the numerous approaches conveyed to you by your education into *suitable combination* with each other!” Finding the correct path to take is, of course, always left to each individual engineer, but the way will be eased by helpful, experienced mentors (of which I was lucky to have a good number). Throughout this process, the thought of

“what I would have wished for in my studies as a development engineer” often suggested itself and remained present in my mind.

Now, since 1995, I have had the opportunity in my “*academic apprenticeship*” at the Technische Universität Dresden to pass on to engineering students my experiences regarding the topic “what I would have wished for in my studies as a development engineer” (in the meantime, alongside the classical courses in electrical and mechanical engineering, also as part of the interdisciplinary major of mechatronics). In this way, my personal teaching loop has been closed, or more correctly my *teaching and learning loop*, as *academic teaching* is most tightly bound to *one’s own learning*.

This present text came into being from many years of teaching “Modeling and Simulation” and “Mechatronic Systems” as part of the primary curriculum in the above-mentioned courses of study.

In the course of this last apprenticeship, it has however turned out that the desired *knowledge transfer regarding system-oriented problem solving in complex heterogeneous systems* can be only approximately realized within the constraints of a time-limited course. It is easy to convey fundamental methodological and conceptual approaches, as well as their implementation in simple practice examples. The space and time required for a broader and deeper technical treatment is simply not available. Bare, weakly-annotated citation of further scientific and technical works to complement a too-brief syllabus really satisfies neither the student nor the instructor. These reasons finally led to “re-working my apprenticeship”, the results of which are presented in this textbook and the basic structure of which is succinctly elucidated below.

Methods, models, concepts

The subtitle of this work is *methods, models, concepts* and arises from the following roots.

Models An awareness of the great importance of *models* in *system development* is based on my own professional experience. Aerospace applications, such as the orbital and attitude control of spacecraft, high-precision pointing, and active vibration isolation for instruments, deal with complex heterogeneous systems. Due to their nature, in today’s conception, these represent *mechatronic systems* par excellence. The development and verification of such systems has, for obvious reasons, always been based on models. System verification and reliable projections of behaviors are primarily based on predictive models. *Model-based system development* and *systems design* thus imply *working with models*. Interestingly, in the last

years, these model-based development approaches have also established themselves in many terrestrial applications, e.g. in the automotive industry, and now represent the *state of the art* for system development in mechatronically-oriented industries.

Methods In order to be able to trust model-based predictions of behavior, the models and dynamic analyses derived from them must be based on a clean technical and scientific foundation. In the context of systems design, this requires suitable *methods of model creation* and of comprehensive *dynamic analysis* of the complete system made up of heterogeneous subsystems. In this context, it is particularly those methods enabling clear, reliable, and simple-to-verify dynamic predictions which are sought after, ranging from feasibility predictions in early project phases up to verifying results from computer-aided design processes (never trust your computer!).

Concepts Systems design—as it includes the term “design”—comprises a most highly *creative* activity. Linked to this are multifarious, intriguing opportunities to exploit available *design degrees of freedom*, to the extent that they and their conditions and boundaries are known. A single monograph can certainly not present a comprehensive view of the material in this sense. This textbook, within the realm of the possible, attempts to present selected and successfully used physical configurations and solution concepts to form the kernels of ideas for one’s own solution approaches. Based on the methodologically oriented conception of this text, topics are presented on the basis of mathematical models in order to indicate paths towards *quantifiable evaluation* of different conceptual variants.

This textbook represents an attempt to place important methodological approaches for the modeling, analysis, and design of mechatronic systems into a common context, and to present them in a systematic and self-contained form.

Acknowledgements

The path is the goal, even if the goal initially appears very clearly formulated. Finding the right path, taking it, and finally also arriving at the original goal, requires—as when climbing a mountain—a trustworthy rope team, to whom, at this point, I wish to pay my heartfelt thanks.

First and foremost, thanks go to my family and particularly my beloved wife Dr.phil. *Ruth Janschek-Schlesinger*. It is not only the period of this summit attempt—and its demands on our personal relationship—which she has accompanied with great understanding and steadfast spiritual sup-

port. It is of particular joy to me that our decades-long partnership has also led to mutual professional synergies. Thus, for instance, she was able to quite successfully integrate systems-oriented problem-solving approaches into her art therapy and supervisory duties, and her spontaneous, artistic, boundary-breaking perspective has opened up many new points of view for me.

For intensive technical discussions and valuable encouragement, sincere thanks are due to my colleagues Prof. Dr.-Ing. habil. *Helmut Bischoff*, Prof. Dr.-Ing. Dr.rer.nat. *Kurt Reinschke* (both of TU Dresden), and Dr.-Ing. *Peter Schwarz* (Fraunhofer Institute for Integrated Circuits, Design Automation Division, Dresden).

A manuscript of 800 pages naturally contains more than a few dangerous pitfalls and stumbling blocks. For their careful and knowledgeable proofreading of the manuscript and their well-founded suggestions for corrections, particular thanks are due to my co-workers Dipl.-Ing. *Martin Beck*¹ (who deserves the medal for times read!), PD Dr.-Ing. *Annerose Braune*, Dr.-Ing. *Eckart Giebler*, Dipl.-Ing. *Sylvia Horn*, Dipl.-Ing. *Thomas Kaden*, Dipl.-Ing. *Evelina Koycheva*, Dipl.-Ing. *Arne Sonnenburg*, and Dipl.-Ing. *Edgar Zaunick*.

I also wish to thank the remainder of my lab group for their continuous understanding of the demands on my time due to this project. Great, sincere thanks are especially due Ms. *Petra Möge*, who throughout the past two years has, with commitment and skill, kept my hands and head free in the administrative realm, and thus established an important prerequisite for the project's success.

I very sincerely thank the ladies and gentlemen of *Springer-Verlag* for their extremely cooperative and trusting collaboration and their considerate handling of the planning of contents and schedule.

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