Biosystems & Biorobotics

Athanasios Karafillidis
Robert Weidner *Editors*

Developing Support Technologies

Integrating Multiple Perspectives to Create Assistance that People Really Want

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Aims & Scope

Biosystems & Biorobotics publishes the latest research developments in three main areas: 1) understanding biological systems from a bioengineering point of view, i.e. the study of biosystems by exploiting engineering methods and tools to unveil their functioning principles and unrivalled performance; 2) design and development of biologically inspired machines and systems to be used for different purposes and in a variety of application contexts. The series welcomes contributions on novel design approaches, methods and tools as well as case studies on specific bioinspired systems; 3) design and developments of nano-, micro-, macrodevices and systems for biomedical applications, i.e. technologies that can improve modern healthcare and welfare by enabling novel solutions for prevention, diagnosis, surgery, prosthetics, rehabilitation and independent living.

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About the Cover

The cover of the book series Biosystems & Biorobotics features a robotic hand prosthesis. This looks like a natural hand and is ready to be implanted on a human amputee to help them recover their physical capabilities. This picture was chosen to represent a variety of concepts and disciplines: from the understanding of biological systems to biomechatronics, bioinspiration and biomimetics; and from the concept of human-robot and human-machine interaction to the use of robots and, more generally, of engineering techniques for biological research and in healthcare. The picture also points to the social impact of bioengineering research and to its potential for improving human health and the quality of life of all individuals, including those with special needs. The picture was taken during the LIFEHAND experimental trials run at Università Campus Bio-Medico of Rome (Italy) in 2008. The LIFEHAND project tested the ability of an amputee patient to control the Cyberhand, a robotic prosthesis developed at Scuola Superiore Sant'Anna in Pisa (Italy), using the tf-LIFE electrodes developed at the Fraunhofer Institute for Biomedical Engineering (IBMT, Germany), which were implanted in the patient's arm. The implanted tf-LIFE electrodes were shown to enable bidirectional communication (from brain to hand and vice versa) between the brain and the Cyberhand. As a result, the patient was able to control complex movements of the prosthesis, while receiving sensory feedback in the form of direct neurostimulation. For more information please visit http://www.biorobotics.it or contact the Series Editor.

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Editors
Athanasios Karafillidis
Laboratory of Manufacturing Technology
Helmut Schmidt University/University of the Federal Armed Forces Hamburg
Hamburg, Germany

Robert Weidner
Laboratory of Manufacturing Technology
Helmut Schmidt University/University of the Federal Armed Forces Hamburg
Hamburg, Germany

and

Chair of Production Technology
University of Innsbruck
Innsbruck, Austria

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The proposal to fund interdisciplinary competence in the field of human–machine interaction to face demographic change by the German Ministry of Education and Research (BMBF) provided an occasion to think different about technology development and its future challenges. In effect, the project smartASSIST was established with the generous support of the BMBF (grant no. 16SV7114). The project executing organization VDI/VDE Innovation + Technik GmbH took care of the necessary formal frame and helped to build up a network of collegiate research groups that emerged out of this research grant. The scientific advisors of our project, Klaus Henning and Philine Warnke, provided many helpful comments and encouraged the whole team to flesh out our conceptual and technological ideas. We are particularly indebted to Jens Wulfsberg, who hosts this project in his Laboratory of Manufacturing Technologies (Laboratorium Fertigungstechnik—LaFT), for providing the necessary research environment and for his steady trust in what we do.

The idea to publish this volume harks back to the second transdisciplinary conference on “Support Technologies that People Really Want” held at Helmut Schmidt University in Hamburg in December 2016. This book is a result of many discussions and exchange that happened during this conference (and beyond). We thank the university for supplying the necessary facilities and in particular the researchers, the staff, and all the other people who helped in one way or another to make it such a wonderful event. The process of compiling the book involves different dynamics, of course. Nothing of this work could have been done without all the authors who committed themselves to contribute to this volume. All of them are exceptional scholars, and we are grateful to have them in this book.

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Athanasios Karafillidis
Robert Weidner

Contents

Contributors

Andrea Altepost Institute for Textile Engineering, RWTH Aachen University, Aachen, Germany

Kaspar Althoefer School of Engineering and Materials Science, Queen Mary University of London, London, UK

Andreas Argubi-Wollesen Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany

Susanne Beck Faculty of Law, Leibniz University Hanover, Hanover, Germany

Peter Biniok Sociologist, Berlin, Germany

Andreas Bischof Junior Research Group "Miteinander", Media Informatics, University of Technology Chemnitz, Chemnitz, Germany

Laura L. Bischoff Institute of Human Movement Science, University of Hamburg, Hamburg, Germany

Gabriele Bleser Department of Computer Science, University of Kaiserslautern, Kaiserslautern, Germany

Sabrina Bringeland Institute of Human and Industrial Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany

Christina Bröhl Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Barbara Deml Institute of Human and Industrial Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany

Annika Fohn Institute for Sociology, RWTH Aachen University, Aachen, Germany

Paul Glogowski Chair of Production Systems, Ruhr-University of Bochum, Bochum, Germany

Yves-Simon Gloy Institute for Textile Engineering, RWTH Aachen University, Aachen, Germany

Bruno Gransche Institute of Advanced Studies FoKoS, University of Siegen, Siegen, Germany

Christina M. Hein Micro Technology and Medical Device Technology, Technical University of Munich, Garching, Germany

Klaus Henning IMA/ZLW & IfU, P3 OSTO, RWTH Aachen University, Aachen, Germany

Jannis Hergesell Department of Sociology, DFG Graduate School "Innovation Society Today", Technical University of Berlin, Berlin, Germany

Daniel Houben Institute for Sociology, RWTH Aachen University, Aachen, Germany

Christoph Hubatschke Department of Philosophy, University of Vienna, Vienna, Austria

Alfred Hypki Chair of Production Systems, Ruhr-University of Bochum, Bochum, Germany

Athanasios Karafillidis Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany

Bernd Kuhlenkötter Chair of Production Systems, Ruhr-University of Bochum, Bochum, Germany

Kai Lemmerz Chair of Production Systems, Ruhr-University of Bochum, Bochum, Germany

Kevin Liggieri Institute for Philosophy I, Ruhr University Bochum, Bochum, Germany

Janina Loh (née Sombetzki) Department of Philosophy, Philosophy of Technology and Media, University of Vienna, Vienna, Austria

Mario Löhrer Institute for Textile Engineering, RWTH Aachen University, Aachen, Germany

Tim C. Lueth Micro Technology and Medical Device Technology, Technical University of Munich, Garching, Germany

Paul Lukowicz German Research Center for Artificial Intelligence, Kaiserslautern, Germany

Arne Maibaum Department of Sociology, DFG Graduate School “Innovation Society Today”, Technical University of Berlin, Berlin, Germany

Klaus Mattes Institute of Human Movement Science, University of Hamburg, Hamburg, Germany

Alexander Mertens Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Jörg Miehling Engineering Design, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Christoph Müller Department for Architecture Theory and Philosophy of Technics, Vienna University of Technology, Vienna, Austria

Peter Müller Munich Center for Technology in Society/Digital Media Lab, Technical University of Munich, München, Germany

Kathrin Nuelle Institute of Mechatronic Systems, Leibniz University Hanover, Hanover, Germany

Tobias Ortmaier Institute of Mechatronic Systems, Leibniz University Hanover, Hanover, Germany

Bernward Otten Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany

Kristin Paetzold Institute for Technical Product Development, University of the Federal Armed Forces Munich, Neubiberg, Germany

Jan-Hendrik Passoth Munich Center for Technology in Society/Digital Media Lab, Technical University of Munich, München, Germany

Peter Rasche Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Arash Rezaey Institute for Textile Engineering, RWTH Aachen University, Aachen, Germany

Johannes Rönnfeldt Institute of Human Movement Science, University of Hamburg, Hamburg, Germany

Katharina Schäfer Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Oliver Schürer Department for Architecture Theory and Philosophy of Technics, Vienna University of Technology, Vienna, Austria

Benjamin Stangl Department for Architecture Theory and Philosophy of Technics, Vienna University of Technology, Vienna, Austria

Agostino Stilli Department of Computer Science, University College London, London, UK

Bertram Taetz Department of Computer Science, University of Kaiserslautern, Kaiserslautern, Germany

Svenja Tappe Institute of Mechatronic Systems, Leibniz University Hanover, Hanover, Germany

Sabine Theis Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Sandro Wartzack Engineering Design, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Karsten Weber Institute for Social Research and Technology Assessment (IST), Ostbayerische Technische Hochschule (OTH), Regensburg, Germany

Robert Weidner Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany; Chair of Production Technology, University of Innsbruck, Innsbruck, Austria

Rebecca Wiczorek Department of Psychology and Ergonomics, Technical University of Berlin, Berlin, Germany

Matthias Wille Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany

Alexander Wolf Engineering Design, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Bettina Wollesen Institute of Human Movement Science, University of Hamburg, Hamburg, Germany

Helge A. Wurdemann Department of Mechanical Engineering, University College London, London, UK

Zhejun Yao Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany

Introduction

Developing. Support. Technologies.

Athanasios Karafillidis and Robert Weidner

The relationship of humans and technology has changed significantly during the last two decades. It has become closer and multiplex—that is, technology has moved closer to the human body and their interconnections have become entangled and diverse. In this vein, technology is envisioned as being able to support or assist human beings more profoundly than ever before. This change has occurred incrementally and is still in progress. It has led to a diversification of possible application areas, a shift in the landscape of innovation projects, and a different perception of technological possibilities in general.

The reasons for this change are manifold. Big societal trends like globalization, individualization, disruptive technological innovations, and demographic pressures are no doubt important for explaining the change in human–technology relations. All of them push political agendas and channel research funds. But when it comes to an understanding of these transformations, they only yield a universal interpretive frame. The recently enforced closeness and multiplexity of human–technology relations are much better understood when taking into account the expanding connectivity, the distribution and increase of computational power, and the plummeting costs of material components and production. Their combination has a high impact on further technological possibilities, but also on the perceptions, needs, and expectations related to technology.

However, this is still only a part of the story. The shift of the relevant relationships is not only a response to such technical or social pressures outside of innovation projects. It is also an inside job. The myriad micro-processes unfolding in the world's

A. Karafillidis (✉) · R. Weidner
Laboratory of Manufacturing Technology, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Hamburg, Germany
e-mail: karafillidis@hsu-hh.de

R. Weidner
Chair of Production Technology, University of Innsbruck, Innsbruck, Austria
e-mail: robert.weidner@hsu-hh.de

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engineering laboratories, in thousands of projects, and in the corporations' research and development departments day by day bring forth different and new relations of humans and technologies. Political claims, technological possibilities, funding interests, scientific progress, legal regulations, cultural images, or market-driven demands no doubt influence them deeply. But societal expectations and demands with regard to technology are themselves profoundly shaped by the very form of organization, the underlying beliefs, and the approaches used in the relevant projects. Thus, the internal reason, as it were, for the observable shift is the advent of a different style of developing technology. This book will argue that the idea of *support* dwells at the center of this shift. It has spawned technological devices that are conceptualized and built with the explicit intention to serve the needs of individuals at work and in everyday life. The objective of this volume is to expound how this is done in detail and what needs to be considered to be able to proceed in a successful as well as responsible way.

Usually, this is considered as the domain of human–machine interaction (HMI). Yet this approach is not equipped to handle the practical, ethical, social, and also technical issues involved. The main lines of this classic program are confined to the interaction of separate units—albeit we are dealing with different forms of entanglement already that blur habitual boundaries and give rise to hybrid entities. Thus, the crucial difference made by a technology that is expected to support, assist, or help people remains obscure when simply seen through the lens of HMI. In contrast, conceiving any human–machine or human–computer interaction and collaboration as support relation gives way to a new approach that certainly draws on the rich tradition of HMI but advances beyond its limitations.

Up to now, discussions about support technologies—from autonomous robots to monitoring systems, wearables, and implants, both in forms of simple tools and complex gadgetry—are preoccupied with engineering issues. It is supposed that if the invented devices are intended to support people, they will do so automatically. This is misleading. No engineering and no design can stipulate the purpose of a device uniquely and unequivocally. A technical invention has to be understood as only one part of a wider support system that also comprises organizational, physical, ethical, legal, and cognitive components. Therefore, the future challenge in research, construction, implementation, and deployment of such systems is twofold. On the one hand, theories and concepts have to be developed accordingly in order to generate fresh, diverse, and surprising perspectives on the relevant problems. On the other hand, new methods and forms of collaboration and evaluation are required to integrate and implement these ideas—in other words, to provide the requisite contexts in which they might grow and get the chance to be cherished and become successful.

This book brings together scholars from heterogeneous disciplines and research fields like biomechanics, engineering, social science, psychology, law, and philosophy to meet this twofold challenge. It integrates both different conceptual perspectives and issues of interdisciplinary development in one volume and sometimes even within single chapters. Since it tries to account for the complex and intertwined technical, social, cognitive, and ethical contexts of technology development and design, this volume gives an idea of how responsible research and innovation is currently realized in developing support technologies. Strictly speaking, the whole endeavor is not about bringing technology to the people. It is about finding ways to design and evaluate technology in tune with the people so that it finds its way to the them in the course of the process—and vice versa.

***

"Developing Support Technologies" is not just some title for this book but rather signifies a research program in a nutshell. The following explanation of the ideas and associations of this title will unfold its main characteristics and substantiate the book's main purpose as well as some of its contents and contentions.

1 Developing—A New Field, a Form of Design/Construction, and Transdisciplinarity

"Developing Support Technologies" has a double meaning that must be considered. On the one hand, "developing" has an active meaning in the sense of bringing technologies forth by designing/constructing, building, and evaluating them. This refers to the setting that there are teams of developers, mostly within departments of profit or non-profit organizations, who work on the implementation of concrete technical solutions for certain specified applications and are preoccupied with managing technical uncertainties [Moh17, Ger15]. On the other hand, "developing" refers to a developing field, a new and therefore necessarily incomplete and sometimes fragile strand of technology and its accompanying societal and organizational uncertainties. This refers to support technologies as a developing area within society in general and engineering in particular [Ois10, Bin17].

The twofold understanding of the title unites the two scientific cultures of engineering on the one hand and the social sciences and humanities on the other. Depending on their scientific background, people read the title in one of these two different meanings. The observable division of work between them does also transpire roughly along these lines. Social science and humanities are more focused on the developing field or certain parts of it and ascertain the accompanying structures and their societal embeddings, while engineering pays more attention to finding feasible and reproducible technical principles that lead to viable, reliable, and tangible material results. Although this kind of division of labor and interest with regard to technology exists, these two groups of disciplines have been getting closer recently since it became obvious that support technologies need to function technically as well as socioculturally. A device that does not work in a technical sense will not be accepted, but a device that triggers fear or requires specialized knowledge or clothing will not "work" either—or will only be accepted under certain conditions or by particular groups. To be sure, this holds for any technology, but the advent of support technologies (also called assistance technologies prematurely) has altered the relevant perspectives. The sociocultural embedding of technology has now become explicit. It is not only accounted for in hindsight but before and during development. The social sciences and humanities are now considered as an important part of the development process more frequently—many remaining obstacles notwithstanding [Vis15].

To develop technology proper has been and still is, to be sure, the work of engineers. They conceive, design, construct, test, and improve composite devices, machines, and systems until they meet the defined requirements. But when it comes to support technologies, this classic form of development is expanded. First, the focus on people with their impression on what counts and their expression of demands alters the technical search for suited materials, proper joints, or adequate programming and favors quickly adaptable devices and simple, intelligible controls. However, the requisite requirements can not be defined once and for all. They are refined and redefined during development on many levels [Suc07, p. 278]. Second, the sequence of development from conception to implementation is not fixed or linear anymore but supplanted by parallel and circular processes. Classic waterfall models of project management have not disappeared, but they fulfill a different function: They provide a rough orientation and legitimize the approach vis-à-vis third parties, like investors and funding agencies. Yet progress in the actual everyday work of research and development is not achieved by sticking to some plan. Mixing up the diverse structures and managing their dissonance allows for an organizational responsiveness [Sta09] that is part and parcel of developing support systems. Third, an augmentation of classic development occurs simply because many more diverse people are involved than before—with various disciplinary backgrounds but also without any academic interest: especially potential users, corporate groups, businesses, social media publics, and further stakeholders.

In short, developing support technologies involve/involves participation, interdisciplinarity, and new organizational forms [Bro15]. The true concept for this threefold augmentation of classical development processes is *transdisciplinarity*: New forms of collaboration have to be found between various scientific disciplines and also between them and potential users, interested citizens, and project partners. To sum up, speaking of *developing* support technologies entails a double perspective and transdisciplinary approaches to collaboration.

2 Support—Different Forms, Structural Properties, and Antithesis to Substitution

The term “support” might sound a little odd in times when most technologies in this vein are labeled as “assistive.” Most of the time these two are used synonymously, but their difference matters. In our conception, support is the generic term. Assistance and help are particular subcategories of support that require distinctive situational structures [Kar17]. Assistance occurs when a task is divided into subtasks and the situationally participating entities, e.g., human individuals and technical devices, are assigned different subtasks in a complementary fashion. Think of the assistant of a CEO or the assistant devices built into modern cars as examples of such a complementary form of support. A tool, in contrast, does not “assist” its user. Even just saying it sounds awkward. Yet there is no doubt that a tool provides support. Also, a mother does not “assist” her children but supports or even helps them wherever possible.

Whether a gadget assists or helps is negotiable and proves to be crucial for its design and acceptance. An exoskeleton enabling a movement that otherwise would be impossible does not assist the individual but rather helps, because it is granted the control over the activity to constitute the movement after all—when help is understood as a form of support that passes the control of the activity in question to the helping entity. When a different exoskeleton is designed to decrease musculoskeletal stress, it supports an activity that could also be performed without it. In this case, neither exactly “help” nor “assistance” do apply for a proper characterization of the unfolding process. Still, it is providing support.

Two general structural properties of support situations (comprising assistance and help) are observer dependence and asymmetric relations. If technology development is attentive to human needs and societal acceptance, it must not ignore that the provision of support lies in the eye of the beholder. This concerns questions about who or what is supporting whom but also whether somebody is assigned support or rather asks for it. Interests, interpretations, and contextual conditions of the observing agencies (i.e., individuals, groups, organizations or other social systems, maybe robots) might lead either to a fierce rejection or to a passionate use of the support system. The other point in case is asymmetry. The development of support technologies must be aware that any support introduces some asymmetry between the supporting and the supported unit, which cannot simply be programmed and settled purposefully in advance [Suc07, pp. 268–269]. Which form of asymmetry prevails in the end can only be identified in frequent field tests and painstaking observation of real use cases in the wild. Often, the time factor of development projects thwarts such a thorough investigation. Yet, first steps into this direction can be clearly recognized. The importance of iteration and external feedback for constructing both responsibly according to human demands and successfully with respect to acceptance has already been realized indeed—albeit there is still way to go for a wider acknowledgment.

In addition to the distinction of different forms of support and the structural properties of support situations, there is a third significant aspect of the “support” component in the book title. Support is, as it were, the antithesis to substitution. Until recently, the sometimes hidden but mainly overt curriculum and objective of technology development has been automation, that is, the substitution of human workforce by machines. The reasons were economic in most cases, like increased productivity, effectivity, and efficiency but also better product quality, less mistakes, improved ergonomic conditions, and not least, to be sure, honorable ambitions to spare humans doing dangerous, risky, and strenuous work.

Many positive effects of automation could be enumerated, and the downsides are also well known [For15, Car14]. It remains a moot point, whether the positive and negative aspects of automation balance each other or not. However, there is an intriguing issue that is more constructive in nature than any debates about loss or gain of jobs. It concerns less the paradoxes, glitches, or unintended effects of automation but rather its pragmatic and practical limits. Certainly, there are a lot of engineers and entrepreneurs who expect that someday any task and activity can be automated. Maybe they will be proven right some day, but this is not the case in point at all. The crucial question is, how we should invest our time and resources to find adequate solutions for the limits and problems we *currently* face.

Engineering research in automation remains important and will no doubt continue. But it should not happen in expense of finding solutions that integrate the skills and awareness of humans with suitable technology. It is important to note that this "integration" exceeds the ideas of interaction and collaboration prevailing in automation engineering. Investing in support technologies receives rightly more attention because when it comes to developing new technology, the substitutionalist paradigm has reached certain limits. Many tasks and activities will not be amenable to automation for a long time to come. For example, anybody who has experienced existing robots for elderly care does immediately recognize this. By implication, human beings will remain pivotal for value creation in plants as well as other formal organizations. Physical skills and human awareness will become even more important in future value chains. Whatever the hopes projected into some indeterminate future: with respect to complex assembly tasks, evaluation, sensorimotor skills, judgment, discretion, the recognition of opportunities, diversity, quick adaptability, heedful perception of weak signals, or situational awareness human beings will remain indispensable.

In short, developing support technologies is/are contingent on a closer inspection of the structural conditions of support and their subtle nuances. Support is the proper answer to the practical limits of automation and to the substitution of human work. To sum up, developing *support* technologies entails to realize that the creation of value and values as well as the evaluation of situations and opportunities cannot abstain from cognition, that is, both awareness and sensorimotor skills.

3 Technologies—Innovation, Customization, and Modularity

Support systems transcend mere technological devices that are devised to assist or support human activities. Yet, the focus on developing support *technologies* is crucial. Having a techno-material structure available or at least imagining some materially tangible device allows to summon all interested participants effectively [Sta89]. It provides a powerful pretense to think about the sociotechnical design of support systems. Other existing forms of support in society—like neighborhood help, emotional and financial support, or assistive functions in hierarchies—lack this summoning material "thing." Presumably, this corresponds to the lack of studies that examine the internal structure of support situations more closely. Studies of "social support" [Hou88] have been preoccupied with structural conditions and individual effects of providing support and less with the inner functioning and patterning of support situations proper. Considering support from the perspective of *technology* urges new perspectives on structure and process of support in general.

Technologies transcend isolated devices. They involve networks of people, skills, material things, certain knowledge, and particular stances to the world [Mac99]. The technical devices in these networks seem like reliable islands of functioning causality that are intimately integrated in a scaffolding of unreliable components. Thus, the concept of "techno-logy"—and not simply: "technics." The Greek word *logos* implies a specific form of reason that accompanies the technics (though not necessarily philosophical reason as a universal). There is always a peculiar logic that pervades technical gadgets and their causal functioning. Next to this "grammar" of technology, there is also a pragmatic knowledge. The term techno-logy indicates that knowledge about construction principles, interaction, and handling is an integral part of its functioning. Finally, technologies are surrounded by a particular wording before, during, and after their development: for example, by justifications and policies, the engineering and design parlance, or the typical marketing vocabulary. In this vein, techno-logy incorporates the syntax, pragmatics, and semantics of a causally constructed material structure that is expected to produce certain determined effects repeatedly and reliably [Ram07, p. 45].

Exactly this societal embedding of technologies also distinguishes mere *inventions* that constantly pop up in laboratories, garages, and institutions on the one hand and durable, accepted, and disseminated structures called *innovations* on the other [Ram10]. Any path to innovation needs to be paved through the muddy grounds of society. Previously, this has been done unconsciously and in passing. In developing support technologies, this aspect is brought to mind explicitly and allows to account for it from the outset. This is not a guarantee for innovation and success but nonetheless gives new design options and some leverage in a process that has been considered stochastic so far.

Technologies are both about *products* and *production*. To develop support technologies means to develop products that people and organizations really want. At the same time, it means to develop technologies that are deployed in the production of products and become part of value chains and production processes—not only in the conventional sense of industrial production but also in the unconventional, generic sense of production, which includes the production of services and private DIY production. The switch to the idea of support tightens the intimate connection of these two aspects.

One of the most salient effects of the support paradigm is the approaching of the human body by technology [Vis03]. This makes any technical product also accessible, deployable, and potentially beneficial for production processes, which are transformed in consequence. From there, new forms of technical products and even innovations can arise. The distant machine hall in which products are produced far removed from everyday life is losing the importance it had since the industrial revolution. The German term "Industrie 4.0," cyber-physical systems, sociotechnical systems, or digitization of production are all expressions of this transformation. Citizen science, the democratization of production, or the character of the "prosumer" characterize the same issues from the opposite side. The same smart gadgets that are used in daily life are now integrated into organized work processes and production plants. An exoskeleton might help the residents of a nursing home to maintain some autonomy but can also be used by the personnel to manage their work load and reduce physical strain.

The proceeding (mass) *customization* of products can likewise be linked to the idea of support. The major response to customization demands is no doubt automation. Today, it is possible to specify the own preferences for a product online and to thereby trigger an automated process in some machine park to produce the desired product that is then automatically packaged and dispatched. Three issues are important in this scenario. First, support technologies need not necessarily operate in the proximity of human individuals. They can be distributed over time and space. Second, support does not necessarily preclude substitution. In the described case the customer is supported to design its own product (within certain limits) while the corporation substitutes human workforce. Third, there are moments in this automated process, for example, quality control, that are difficult to automate. Furthermore, there are also sectors where customization depends completely on human skill, for example, the construction and adaptation of prostheses, many forms of surgery, haircuts, all forms of nursery, or most products of construction industry, especially the completion of the interior. The people involved in such customization procedures are already supported by proper software or (smart as well as classical) tools but there is much more potential, in particular with respect to physical support.

A last facet of this unfoldment of the volume title is the necessary plural of "technologies" in connection to support. It should have become clear that support itself cannot be automated. It is the customized product per se because it involves and generates hybrid entities that merge certain activities, human bodies, technical devices, perceptions, norms, and social situations. That is, there will always exist *many* suitable support solutions for diverse activities and contexts—but also for seemingly identical activities and contexts. The latter points to another crucial engineering challenge in developing support technologies: to achieve *adaptability* and *modularity*. Since the hybrid combination of the human body, its perceptional capabilities, and technical equipment has to be considered as unique in every situation, the standardization prospects are disappointing. Support technologies are thus drivers of devising new forms of technical adaptability to bodies, perceptions, and situations with the objective to form *one integrated system*.

This adaptability can also be achieved by inventing modular solutions. Modularity, however, also refers to a more intriguing, though very challenging, aspect: the modularity and customization of support that is achieved by coupling different technical systems which in turn requires the construction, standardization, and design of compatible interfaces for different components of support systems. That is, for example, various interfaces for signal and information transfer, energy transmission, physical contact surfaces, or handling and control. Both variability within interfaces and between interfaces are highly relevant.

In short, support technologies are embedded in a whole apparatus of non-technical components and rely on them to function properly. Innovations come from finding a proper fit between all of these components. To sum up the consequence, developing support *technologies* pose/poses some challenges for engineering. They compel the profession to rethink the connection of products and production, to reconsider the relation of automation and customization, and to develop adaptable and modular systems as well as relevant interfaces that make them compatible.

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The contributions in this book display the diversity of the people, disciplines, and topics in this field of research. Not all of the above aspects of the presented research program are discussed in this publication. However, the diversity is explicit, and its management is not an easy task. This includes the editing of the book. We selected distinguished scholars that are not only experts in their respective field but who additionally have some experience with participatory and interdisciplinary research projects regarding technology development for support. As editors we had a general concept for the book in mind and targeted the relevant researchers to send us articles treating a particular subfield, presenting subject-specific views on support systems, or reporting about deployment contexts from the perspective of their expertise.

The chapters that made it into the book are grouped into four major parts: "Demands and Expectations," "Constructing and Construing," "Forms and Contexts of Deployment," and "Values and Valuation." They are followed by two concluding chapters that discuss some prospective further developments of (support) technologies. The four parts represent main clusters of research activities in developing support technologies. They seem to form a sequence, but this is owed to the book format only. More likely, they set up a circular process. Starting with a demand analysis seems natural, but there are already valuations in place or earlier prototypes that lead to certain demands. Furthermore, all of these activities run concurrently in relevant projects and permanently influence each other. This implies that none of these discrete yet interfaced "stages" is ever completed as long as the project unfolds. Demand analysis is an ongoing concern in the development of support technologies as are valuation, construction, and deployment.

The main ideas framing each subsection and short introductions to the individual chapters are given in brief introductory notes at the beginning of the book parts. Due to the just mentioned circularity and simultaneity of the empirical processes, there are overlaps. Some of the articles could appear in more than one subsection. Yet there are good reasons to arrange them this way. One of the editorial decision premises in this respect has been to demonstrate the multiplicity of perspectives within each research cluster as represented by the subsections of this volume. We have decisively refrained from making special sections for, e.g., science, engineering, and humanities. There are no leading disciplines in any of the research areas for developing support technologies.

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The papers collected here come from many different disciplines. The volume contains inputs from biomechanics, engineering, information science, philosophy, psychology, and the social sciences—to name only the most generic denominations and sparing the internal specializations. Each of the chapters cherishes its own terminology and quirkiness. All of them, however, can also be read by researchers who are not familiar with the subject-specific debates of the disciplines. The language they use is generally intelligible. Despite that, no article is able to deny its origin and background. Such a denial or disguise of disciplines would have been detrimental to the idea of this book. A seminal reference between disciplines is only possible when the *difference* between them is retained and accepted.

Certainly, to some extent this book displays the personal, regional, and institutional networks of the editors and their research group. But this Central European bias is not simply accidental. The *transdisciplinary* research community on technical support systems is actually prevalent in Central Europe. This may be due to research policy decisions or some other factors not yet explored. In the end, it may be just our ignorance. But there is no doubt that an international publication putting the common thread of these multiple perspectives on developing support technologies into focus is overdue. In this respect, this book is also an appeal asking for further international communication and collaboration in this developing research field—and also an appeal to prove us wrong that the form of transdisciplinary research on support technologies as expounded in this introduction is mainly happening in Europe (see, however, [Ois10] and [San14] with similar ambitions). Any further information and suggestions are welcome by the editors as well as all of the contributors.

This collection and arrangement of research papers is not the classic "how to" book. It contains reflections and descriptions of the different processes that accompany any development of support technologies. Its effect is a change in perspective and this generates, then again, we hope, a plethora of ideas how to approach and implement one's own projects. Therefore, it is a book of research in two respects. First, it allows to observe and thus research how support technologies are developed; and second, it gives some leverage to do research based on these suggestions and experiences from others.

References

[Bin17] Biniok, P., & Lettkemann, E. (Eds.). (2017). *Assistive Gesellschaft. Multidisziplinäre Erkundungen zur Sozialform "Assistenz"*. Wiesbaden: Springer VS.

[Bro15] Brown, R. R., Deletic, A., & Wong, T. H. F. (2015). How to catalyse collaboration. *Nature, 525*, 315–317.

[Car14] Carr, N. (2014). *The glass cage. How our computers are changing us*. New York: W. W. Norton.

[For15] Ford, M. (2015). *Rise of the robots. Technology and the threat of a jobless future.* New York: Basic Books.

[Ger15] Gerke, W. (2015). *Technische Assistenzsysteme. Vom Industrieroboter zum Roboterassistenten*. Berlin et al.: Walter de Gruyter.

[Hou88] House, J. S., Umberson, D., & Landis, K. R. (1988). Structures and processes of social support. *Annual Review of Sociology, 14*, 293–318.

[Kar17] Karafillidis, A. (2017) Synchronisierung, Kopplung und Kontrolle in Netzwerken. Zur sozialen Form von (technischer) Unterstützung und Assistenz. In P. Biniok & E. Lettkemann (Eds.), *Assistive Gesellschaft* (pp. 27–58). Wiesbaden: Springer VS.

[Mac99] MacKenzie, D. & Wajcman, J. (Eds.). (1999). The social shaping of technology (2nd ed.). Buckingham: Open UP.

[Moh17] Mohammed, S., Park, H. W., Park, C. H., Amirat, Y., & Argall, B. (2017). Special issue on assistive and rehabilitation robotics. *Autonomous Robots, 41*(3), 513–517.

[Ois10] Oishi, M. M. K., Mitchell, I. A., & Van der Loos, H. F. M. (Eds.). (2010). *Design and use of assistive technologies. Social, technical, ethical, and economic challenges*. New York et al.: Springer.

[Ram07] Rammert, W. (2007). *Technik – Handeln – Wissen. Zu einer pragmatischen Technik- und Sozialtheorie*. Wiesbaden: VS Verlag.

[Ram10] Rammert, W. (2010). Die Innovationen der Gesellschaft. In J. Howaldt & H. Jacobsen (Eds.), *Soziale Innovation. Auf dem Weg zu einem postindustriellen Innovationsparadigma* (pp. 21–51). Wiesbaden: VS Verlag.

[San14] Sankai, Y., Suzuki, K., & Hasegawa, Y. (Eds.). (2014). *Cybernics. Fusion of human, machine and information systems*. Springer Japan.

[Sta89] Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–1939. *Social Studies of Science, 19*, 387–420.

[Sta09] Stark, D. (2009). *The sense of dissonance. Accounts of worth in economic life*. Princeton: Princeton UP.

[Suc07] Suchman, L. (2007). *Human-machine reconfigurations. Plans and situated actions* (2nd ed.). Cambridge: Cambridge UP.

[Vis03] Viseu, A. (2003). Simulation and augmentation: Issues of wearable computers. *Ethics and Information Technology, 5*, 17–26.

[Vis15] Viseu, A. (2015). Integration of social science into research in crucial. *Nature, 525*, 291.

Part I
Demands and Expectations

Technology is pervaded by narratives that justify the effort of their development. A permanent feature of such inevitable narratives is the presentation of technical solutions as responses to some demand or need. This feature is reflected, for example, in the "motivation" of engineers or in the well-known requirement specifications. Yet it makes a difference where the recounted demands come from. Most ideas still emerge out of what is technically feasible and then look for external demands to which they appear as an answer. To be sure, this does not mark a problem per se. Such a technology-driven practice has its own edge. But starting with an analysis of situated and domain-specific demands, no doubt makes a difference—in particular when acceptance is an issue.

Developing technical systems in response to demands is the first and crucial step to increase the probability of their acceptance. Demands of potential users and stakeholders can be surveyed by observing people and practices, body movements and task environments, routines and interactions. Various methods exist to get the requisite observations, e.g., diverse interview techniques, experimental setups in the laboratory, participant observation, field tests, or ethnographies. To yield an expedient input for engineering, the gathered data is used to reconstruct the multiple conditions of work and life, in which the contrived technology is to be integrated. Potentials, possibilities, and risks of a support technology entering the users' worlds can be induced from there.

Although demand analysis is rightly understood to mark the beginning of some project, it is also important to realize that it is an ongoing accomplishment. Demands and needs are not stable but shift in time. They change when a prototype comes into play, when technology is utilized or deployed in other contexts, or after it is evaluated and further optimized.

All in all, demands—including needs, acceptance, and usability issues—represent the *expectations* in the relevant field and explain its dynamics. The expectations of stakeholders are heterogeneous and do often differ from those of the prospective users, and both in turn differ from those of the involved journalists, managers, or politicians. Any analysis of demands (and thus acceptance) is contingent on the field of further expectations connected to the solutions and the project in general. Thus, demands and acceptance should not be treated separately. Their analysis goes hand in hand. Both are part of the web of expectations surrounding, informing, and driving the respective project.

This first subsection of the book summarizes different approaches from diverse disciplines to expound what is necessary for a suitable analysis of demands and expectations in developing support technologies. In detail, they are considered with regard to sociotechnical arrangements, human practices, meaning, bodily mechanics, societal trends, and the phenomenal worlds we perceive and inhabit.

Peter Biniok starts with a piece that sets the general stage. He argues that any development of support technology takes place in "sociotechnical assistance ensembles." He stresses the importance of fine-grained negotiation practices in such arrangements and describes relevant processes and structural features. Practitioners thus get an impression of the overall expectational dynamics in a project and gain an understanding of how seemingly "soft" factors constitute "hard" technology and become vital for the success of the technical solution and the endeavor as a whole.

Kristin Paetzold continues with the presentation of a technique that can be used to analyze needs of (older) people to find leverage points for technical support. The proposed practice-centered analysis of needs takes into account the local and material contexts of older people's immediate lifeworlds and then looks at the practical strategies they develop to deal with everyday problems. Any need for support can be understood with more precision when routines and practices are observed in local environments. The gained insights can be put to use for product development, as Paetzold argues in conclusion.

Kevin Liggieri opens up a historical perspective that helps to understand the role of meaning in relations of humans and technology. Searching for technical structures with a high probability of acceptance, the early discipline of psychotechnics had contrived the concept of "Sinnfälligkeit" which described how technical and material structures made sense to human users when they matched their mental and corporeal structures. Technical systems have to make sense, to fall into place, and to generate meaning. What is now called "intuitive control" does not only have historical predecessors, but the account of Liggieri also highlights that the acceptance of technology is a question of embodied meaning and sense-making.

With the contribution of *Andreas Argubi-Wollesen* and *Robert Weidner*, we move on from sociotechnical, material, and cultural demands to understanding and measuring demands of the human body. The authors present the distinctive challenges posed by the human body and its movements for the development of physical support technologies, i.e., exoskeletons, and give an overview of expedient tools. They contend that there is no single best method but only a suitable mixture of different methods that have to be selected and recombined for each research and development project anew.

Local and situated demand analysis for support technologies can be complemented by harnessing, as it were, the law of large numbers. *Alexander Mertens, Katharina Schäfer, Sabine Theis, Christina Bröhl, Peter Rasche,* and *Matthias Wille* shift the perspective to such large-scale measurements of societal dynamics and trends. The mass survey techniques presented by the authors help practitioners to identify general demands belonging to a certain social group (users, customers) and to understand how these technological demands and expectations change over time.

At the end of this first part of the book, *Bruno Gransche* inquires into how technical support/assistance is finding its way into our lifeworlds and how this reshapes our relations to technology. His arguments point to an aspect that is ignored in technology development most of the time, namely, that assistance is a thoroughly two-sided affair. This is not only a reminder that unintended consequences may emerge. Instead, it addresses the very practical issue that any analysis of expectations and demands should be extended to include the expectations of developers and stakeholders. Gransche exemplifies this by showing that the prevalent idea of bringing relief to the people by support technologies remains flawed if the burdens of assistance are ignored.

What is a factual relief for one group of people might be a burden for another; what is a relief at one point in time might turn out as a burden some time later; and what gives relief in the performance of one task might appear as a burden when performing a different task. This inevitable two-sidedness of expectations is not a "nice-to-have" insight. Rather, it has severe practical consequences for issues of acceptance and must be taken into account to develop sound, sustainable, and successful technical support systems that people really want.

Sociotechnical Assistance Ensembles. Negotiations of Needs and Acceptance of Support Technologies

Peter Biniok

Abstract Questions of needs and acceptance of support technologies are negotiated in sociotechnical assistance ensembles. Sociotechnical assistance ensembles are discussed as analytical tool, which overcomes both the dichotomy of social issues and technology as well as the distinction of technology development and use. In this way, it is possible to take all relevant heterogeneous actors (humans as well as technologies) into account and explore their relationships during technization procedures. The development of support technologies is at best a participatory, multidisciplinary, transformative, and ecological process.

1 Introduction: Assistance, Technology, and Society

Present society is (also) an assistive society [Bin17a][1]. *Assistance* is observable in various forms, such as care and cooperation among people (laboratory assistant), help by simple technologies (navigation device) or collaboration in complex configurations of social actors and technical entities (computer-assisted surgery). Especially the latter form of ever closer exchange between humans and support technologies has steadily been increasing in the past few years. This affects not only the use and distribution (*acceptance*), but also the design and development (*needs*) of support technologies. Technical sociology [Ram07] and science and technology studies [Hac07] deal with these processes of innovation, technization and utilization, and investigate the interdependencies between humans and technologies.

On the one hand, technologies are shaped by social, cultural, economic and other factors (social constructivism). For instance, depending on the local conditions in laboratories, technologies vary over place and time, even if the basic functions are the same. On the other hand, technologies effect society (technological determinism). They enable or prevent actions of people, e.g., doors grant access and/or stop thieves.

P. Biniok (✉)
Sociologist, Berlin, Germany
e-mail: peter.biniok@freenet.de

[1]This work is based on the more detailed proceeding [Bin16a].

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